1945 Progress Report on Pollution of Oregon Streams

By

FRED MERRYFIELD

and

W. G. WILMOT

Bulletin Series, No. 19

June 1945

Cooperating Agencies

Oregon State Sanitary Authority
League of Oregon Cities
Oregon State Game Commission
Oregon State Board of Health
Hydro-Electric Commission of Oregon
Engineering Experiment Station

Engineering Experiment Station
Oregon State System of Higher Education
Oregon State College

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(2) To serve the industries, utilities, professional engineers, public departments, and engineering teachers by making investigations of interest to them.

(3) To publish and distribute by bulletins, circulars, and technical articles in periodicals the results of such studies, surveys, tests, investigations, and researches as will be of greatest benefit to the people of Oregon, and particularly to the state's industries, utilities, and professional engineers.

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Corvallis, Oregon

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Beautiful Willamette

From the Cascades' frozen gorges,
Leaping like a child at play,
Winding, widening through the valley,
Bright Willamette glides away;
Onward ever,
Lovely river,
Softly calling to the sea,
Time that scars us,
Maims and mars us,
Leaves no track or trench on thee.

—*Sam L. Simpson*

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1945 Progress Report on Pollution of Oregon Streams

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Field Engineer

I. INTRODUCTION

1. **Foreword.** This is a report of pollution studies conducted during 1944 of certain public waterways and sources of municipal sewage and trade wastes in the state of Oregon. Because of the far-reaching effects of the findings of these studies it is anticipated that this report will be of interest and of value not only to the sanitary engineer, the public official, or the manager of industry who is directly concerned with stream pollution problems, but also to the average citizen who is interested in the general welfare of his state. For this reason the authors have, wherever possible, used the language of the layman in preparing this report.

The material in this bulletin will be especially valuable to those cities and industries that participated in the studies, because it provides them with data pertinent to the design of their individual sewage treatment and waste disposal projects. In addition, it provides the State Sanitary Authority with information regarding the extent of pollution already present in certain streams and, therefore, forms the basis for accurately determining the required type and degree of treatment for the various sources of pollution.

In making these studies a more widespread interest in the subject of stream pollution control has been created among individuals throughout the entire state. This increase in interest has been extremely helpful in getting public officials to make definite progress in their plans for the postwar construction of stream pollution abatement projects.

Realizing the value to certain communities of the information already obtained, the League of Oregon Cities has requested that the studies be continued during the year 1945. In response to this request, the State Sanitary Authority has been provided with the necessary funds, and arrangements have been made with the personnel of the Engineering Experiment Station to continue this service.

State Sanitary Authority
May 1945

KENNETH H. SPIES,
Acting Director and Secretary

2. **Authorization.** On June 30, 1944, with the approval of Governor Earl Snell, the Postwar Readjustment and Development Committee for the state of Oregon resolved that the State Sanitary Authority, State Game Commission, State Board of Health, Hydro-Electric Commission, and Engineering Experiment Station of Oregon State College be called upon to furnish facilities, personnel, and funds necessary for conducting stream pollution studies; that such studies be for the purpose of providing cities, industries, the state of

Oregon, and interested individuals with facts pertinent to the design of postwar pollution abatement projects; and that the studies be conducted under the direction of the State Sanitary Authority and an advisory committee consisting of one representative from each of the contributing and participating state agencies. On July 12 the State Sanitary Authority was informed that the necessary funds had been made available.

On July 14, 1944, on the call of Mr. H. F. Wendel, Chairman of the State Sanitary Authority, the first meeting of the Advisory Committee was held. The following, who were all in attendance, were recognized as the official representatives of the several cooperating agencies:

MR. H. F. WENDEL	Chairman, State Sanitary Authority
MR. K. H. SPIES	Acting Director and Secretary, State Sanitary Authority
MR. F. C. INKSTER	President, League of Oregon Cities
MR. HERMAN KEHRLI	Secretary, League of Oregon Cities
MR. E. E. WILSON	Chairman, State Game Commission
DR. F. D. STRICKER	Secretary, State Board of Health
MR. F. C. DILLARD	Vice-Chairman, Hydro-Electric Commission
PROFESSOR FRED MERRYFIELD	Engineering Experiment Station

On July 19 the Advisory Committee again met and authorized the Engineering Experiment Station to proceed immediately with the stream pollution studies as set forth in the resolution of the Postwar Readjustment and Development Committee. Professor Merryfield was named as Supervising Engineer for the project. The studies reported upon in this bulletin thus were officially initiated on July 19, 1944.

3. **Acknowledgments.** The survey and report were completed under the direct supervision of the Engineering Experiment Station of which S. H. Graf is Director. Professor J. E. Simmons, of the Department of Bacteriology, supervised the bacteriological analyses made by Miss Phyllis Kachelhoffer. Professor J. P. Mehlig, of the Department of Chemistry, supervised the general chemical procedures and carried on some of the routine laboratory analyses.

The main laboratory testing was carried on by Mr. Fred G. Kachelhoffer, who worked devotedly and daily throughout the survey without a day's rest. Messrs. J. R. Spencer and M. J. Shepherd worked part of the time on many of the routine tests.

The field work, consisting of river sampling and city sewage collections, was well performed by Messrs. Harvey Sachs and W. G. Wilmot, Jr. A strict time schedule was maintained by these two field men throughout the summer and Mr. Sachs collected city sewage samples to the end of the survey. Professor R. E. Dimick, of the Department of Fish and Game Management of Oregon State College, along with Mr. R. O. Ballantyne, furnished many additional river samples and made observations of the river that were of great value to the whole survey. Throughout the work, Professor Dimick contributed untiring effort and enthusiasm that lightened the burden of the authors. Thanks are due to Misses Barbara MacKay and Rebecca Robison for their unfailing courtesy and efficiency in taking care of the many details connected with the recording of data and preliminary preparation of manuscript. Final preparation of manuscript, before submission for publication, was performed by S. H. Graf assisted by Mrs. Alura Paul.

Without the efforts of the city engineers and their sampling crews, it would have been impossible to obtain the great number of sewage samples. Many of the crews worked the clock around obtaining hourly samples, compositing them,

and recording pertinent data. These samples were picked up by the field crew, and it is notable that no sample was lost throughout the survey, despite a most difficult truck schedule that had to be maintained throughout the program. Many of the city engineers, confronted with extraordinary demands on their time, sampled during the evening hours or early morning in order to take advantage of the opportunity. Their efforts are appreciated, and a list of the cities with the engineers and superintendents is as follows:

Springfield	Paul Basford
Eugene	W. C. Clubb
Harrisburg	H. McEldowney
Corvallis	V. P. Goodnight
Albany	W. W. Larsen
Lebanon	E. C. McClain
Independence	M. M. Nelson
West Salem	E. D. Cook
Salem	J. H. Davis
Mt. Angel	Jacob Berchtold
Sheridan	L. M. Kaufman
McMinnville	M. H. McGuire
Newberg	F. C. Colcord
West Linn	A. G. Volpp
Oregon City	J. L. Franzen
Gladstone	A. D. Paddock
St. Helens	D. C. Slaght
Oswego	J. E. Duis
Hood River	Ed. Hobson
The Dalles	Homer Wall
Pendleton	F. B. Hayes
Milton	Homer Kramer

The cooperation of the city councilors and mayors is appreciated. Mr. F. C. Inkster, Mayor of Oswego and President of the League of Oregon Cities, with Mr. Herman Kehrli, Executive Secretary of the League, generously supported the whole survey.

Special mention must be made of the work and help of Mr. Charles Daley, County Sanitarian of Umatilla County, and Mr. Matt Mimms, of Pendleton, who helped with the laboratory work while the field laboratory was in that city.

The assistance given by Messrs. W. J. Moore, N. Hotaling, George Easton, and other members of the Eugene Water Board staff, was valuable and is sincerely appreciated.

The recording of daily river temperatures and conditions by the ferrymen at Peoria, Buena Vista, Independence, Wheatland, and Wilsonville was of considerable value. Thanks are due these men for their unfailing courtesy and help.

We gratefully acknowledge the cooperation of the following industries: Reid Murdock, Hunt Brothers, Kelly Farquhar, California Pack, Sick's Brewery, Miles Linen Mill, and Cascade Packing Plant, all at Salem; Eugene Woolen Mills, Brownsville Woolen Mills, Pendleton Woolen Mills, Monroe Flax Plant, Nebergall's Packing Plant, Spencer Canning Company, Weyerhaeuser Timber Company, Crown-Zellerbach Corporation, The Dalles Cannery, and Mt. Angel Creamery.

Individual thanks are due Governor Earl Snell; Mr. G. C. Aiken, State Budget Director; Mr. E. E. Wilson, Chairman of the State Game Commission; Mr. H. F. Wendel, Chairman of the State Sanitary Authority; Mr. C. C. Stricklin, State Engineer; Dr. F. D. Stricker, State Health Officer; Mr. K. H. Spies, Acting Director and Secretary, State Sanitary Authority; Mr. F. C. Dillard, of the State Hydro-Electric Commission; Dr. E. L. Wells, Director U. S. Weather Bureau; Mr. George Canfield, District Engineer, U. S. Geological Survey; Dean G. W. Gleeson, School of Engineering; Professor S. H.

Graf, Director of the Engineering Experiment Station; Dr. C. A. Mockmore, Head of the Civil Engineering Department; Professor J. C. Burtner, College News Bureau; Dean F. A. Gilfillan, School of Science; Dr. E. C. Gilbert, Head of the Department of Chemistry; Professor G. V. Copson, Head of the Department of Bacteriology; Mr. C. H. Bryant, Curator of Laboratories; Miss M. M. Field, Engineering Librarian; Dean P. M. Dunn, School of Forestry; and Dr. Edward Locke, Chemical Engineer, Pacific Northwest Forest and Range Experiment Station, U. S. Forest Service.

The cooperation shown the members of the survey by the many people of the State of Oregon contributed to make the work of this survey a pleasure and a success.

II. SUMMARY OF OBJECTIVES AND CONCLUSIONS

1. **Purposes.** There were three related purposes in making the survey:
   a. To determine the sanitary conditions of the Willamette River and its tributaries and compare these findings with those of the 1929-30 Survey.[1]
   b. To determine the sewage and industrial waste load now imposed upon the river.
   c. To determine the effect of these wastes on the fish life of the river.

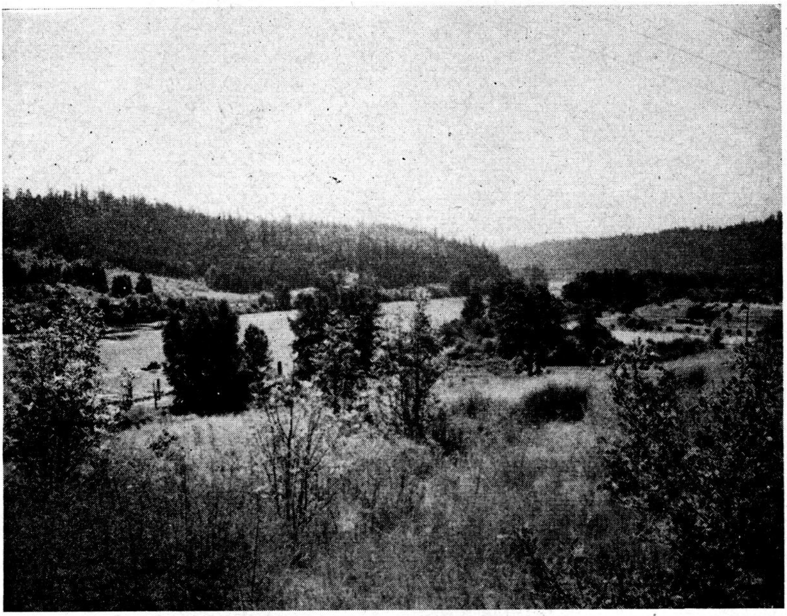

Figure 1. WILLAMETTE RIVER AT WEST LINN.

[1]Bulletin No. 1. Preliminary Report on the Control of Stream Pollution in Oregon, by C. V. Langton and H. S. Rogers, 1929. Oregon State Engineering Experiment Station.
Bulletin No. 2. A Sanitary Survey of the Willamette Valley, by H. S. Rogers, C. A. Mockmore, and C. D. Adams, 1930. Oregon State Engineering Experiment Station.

2. **Sampling points and procedures.**
   a. All sampling and tests of water and sewage were made according to *Standard Methods of Water and Sewage Analysis,* 8th Edition, 1936. Where no standards had previously been established a fixed procedure was adopted and rigorously adhered to.
   b. Sampling of fish, food organisms, and benthal conditions of the river were made according to standard procedures as described in a companion bulletin, No. 20.[1]
   c. The condition of the Willamette River was determined by periodic tests at sampling points corresponding to those critical stations employed in 1929. Additional samplings were made at all other stations of the 1929 survey and at a number of new stations on the Willamette and its tributaries.
   d. Proportioned samples of city sewages from trunk line sewers of 21 cities taken hourly and composited for twenty-four hours were analyzed in the laboratory. These samples were collected on a staggered schedule so that the daily variation in quality and quantity throughout the week would be reflected in the final data. Sampling started July 30 and ended November 26.

      Several cities installed weirs and recording instruments for measurement of the flow of sewage. Estimates of the flow of sewage in other cities, where weirs and instruments were not used. were made by float tests on controlled sections.
   e. Spot and representative samples of industrial wastes from 18 industries were taken and analyzed. Some quantitative estimates were made of these wastes.

3. **Conclusions.**
   a. The Willamette River was found to be seriously contaminated during the summer and fall for several miles below the following towns: Cottage Grove, Eugene, Corvallis, Albany, Salem, Newberg, and Oregon City. The river in these sections is unfit for swimming and as a source of domestic water supply without complete purification treatment. In fact, below Eugene, Salem, Newberg, and Oregon City the river water should not be used as a source in any event.

      Certain tributaries such as Rickreall, South Yamhill, South Santiam, and Pudding are severely contaminated.

      The Umatilla River below Pendleton is seriously contaminated. Small creeks in the same area in proportion to their flow receive considerable sewage load.

      The Willamette River is badly polluted from Salem to Portland. No atmospheric oxygen was found in the river at Wilsonville and Willamette on three occasions. Throughout the length of the river there was considerably more pollution than existed in 1929. The river has degraded upstream rapidly since 1929. Treatment of domestic sewages and industrial wastes will stop this action and improve the sanitary and oxygen quality of the water.

      Full discussion of the survey in respect to fish and fish food organisms will be found in companion Bulletin No. 20.

[1]Bulletin No. 20. The Fishes of the Willamette River System in Relation to Pollution, by R. E. Dimick and F. Merryfield, 1945. Oregon State Engineering Experiment Station.

b. Variations in quality and quantity of city sewages cannot be enumerated in this summary, but the following conclusions are pertinent. The quantities of these sewages were seriously affected by infiltration in both sanitary and combined sewers. Many sewers were broken down or clogged. Some of those sewers serving the dual purpose of sanitary and storm flow drainage have outlived their usefulness. Several cities have no interceptors and discharge their sewage above low water along the river bank throughout the length of the city. An organized plan of replacement of combined sewers with sanitary sewers over a twenty or thirty year period might be economical.

Few cities discharged strictly domestic sewage into the rivers. Most sewages are mixed with industrial wastes from canneries, creameries, flax retting plants, packing houses, and textile plants. Such combined wastes make the treatment of city sewage more difficult and expensive. Increases in strength and variations in quality emphasize the difficulties. Secondary treatment of such city sewages during the low flow period is necessary. Careful study should be made by cities before acceptance of such wastes is made.

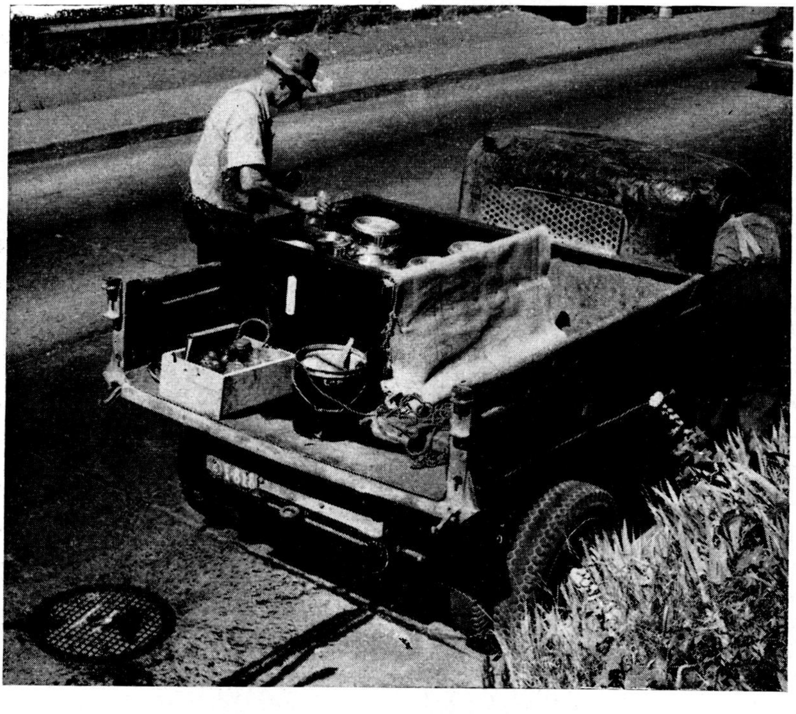

Figure 2. SAMPLING CREW AND APPARATUS AT OREGON CITY.

c. Industrial wastes varied in quality and quantity throughout the survey period. Each waste is a separate problem and was investigated as such within the limitations of time imposed by the other parts of the survey.

Production of power and steam from evaporated sulfite liquor has been perfected by one member of the pulp and paper industry in the Northwest. Considerable research and money has been and is being devoted to other solutions of this problem.

Widespread canning and packing of fruit and vegetables has been developed over the state and particularly in the Willamette, Umatilla, and Walla Walla valleys in the past fifteen years. Waste disposal from these plants into the rivers and on the land has increased rapidly. There is urgent need for intelligent research on the utilization of this material, which is at present an economic loss to all concerned and a large pollutional burden on the rivers.

Increase in irrigation in the Willamette Valley will emphasize this in two ways: (1) increase in wastes from more manufactured products, and (2) decrease in flow, unless augmentation of river flow from storage dams at critical periods offsets this.

Introduction of still-bottom wastes from the proposed alcohol plant at Springfield will unquestionably severely pollute the stretch of river from Eugene to Independence unless alleviation treatment is provided.

Increase in flax production in the Willamette Valley has added no inconsiderable burden to the drainage system of the valley.

Other industrial wastes equally strong are not as large, but still impose their waste loads untreated on the rivers and are responsible for their share in the degradation of the rivers.

Reaeration and deoxygenation rates of the Willamette River should be established by actual field tests before organic loads from treated sewages are imposed.

The river should be sampled throughout its length continuously to establish the general effect of treatment plants when placed in operation, and the effluents from these plants should be sampled and analyzed to check the efficiency of such plants with respect to the purposes for which they were designed.

The cost of this treatment will be large and a direct tax on the people of the State; therefore, every effort should be made to obtain maximum benefits with minimum costs. It should be pointed out that operating costs are continuing costs, and that the building of treatment plants is but one part of the picture. Efficient operation of them is just as important as reasonable first cost.

III. FUNDAMENTALS OF STREAM POLLUTION

1. **Original conditions and their unbalance.** Five major characteristics determine the nature of an originally stabilized stream: volume of flow, the saturated dissolved oxygen content, temperature, the biology of the river, and its hydraulic characteristics. The introduction of human and industrial wastes depletes the oxygen content and disturbs the biological balance.

There is a continual slow replenishment of oxygen from the air and from vegetable water organisms that produce oxygen in the presence of sunlight. This does not produce oxygen in sufficient quantities, however, to satisfy the demands made by domestic sewage, augmented during periods of low river flow by large industrial wastes. These wastes may result in complete exhaustion of the dissolved oxygen. The depletion does not occur at the point of discharge, since even the partial oxidation of waste matter requires several days. Because of the phenomena of slow oxidation, reaeration, mixing, and additions of flow and wastes it is impossible to determine quantitatively by analysis of the river the exact contributory responsibility of each upstream waste. It is, however, possible to approximate the effect of any given waste by measurement of its quantity and its oxygen demand under controlled conditions.

2. **Effects of wastes.** The volume of flow multiplied by a suitable factor expressing atmospheric dissolved oxygen gives the total oxygen content of the river at a given point. This volume of atmospheric oxygen dissolved in the river is the factor that makes fish life possible and keeps the river fresh. Addition of oxygen-demanding waste depletes this capital stock and may ultimately exhaust it beyond the point of recovery. Similarly, the volume of sewage and industrial wastes introduced into the river multiplied by the biochemical oxygen demand (BOD) and a suitable factor gives the total weight of oxygen preempted by this waste for an ensuing specified period.

If the available oxygen supply is exceeded by the successive oxygen demanding wastes introduced at several places along the river, and reaeration is insufficient to make up this deficiency, then septic conditions will prevail downstream from the points where the wastes were introduced. Additional wastes added at this point where septic action begins create and maintain a stretch of river where higher forms of aquatic life disappear. This septic zone, devoid of life-sustaining oxygen, forms an impenetrable barrier through which food and game fishes cannot pass in the instinctive migrations of their life cycles.

This condition, while it does not occur throughout the entire year, does occur in the low flow period of summer and fall on the Willamette River. On the Willamette this septic condition usually coincides with high temperature conditions and consequent low initial oxygen content, heavy seasonal industrial waste disposal, the upstream and downstream migrations of salmon, and the period of the year when human intestinal infection is more probable and when recreational uses by the public are in greatest demand.

Future additional domestic and industrial wastes will extend both the period of time and the septic length of the river. This destruction of recreational assets and other economic values, and the imposition of definite sanitary hazards, will relegate the Willamette River to the position of an embarrassing liability instead of an economic and aesthetic asset.

The disposal of domestic and industrial wastes in the Willamette Valley is becoming increasingly detrimental to the receiving streams where sewage treatment is not practiced. This is the unavoidable consequence of an increasing population and intensified industrial activity. In the majority of instances the industrial growth is more rapid than the increase in population, due to introduction of new processes and the processing of more commodities. Most of these processes require large volumes of pure water. An additional potential load may be predicted by new sanitary disposal methods for kitchen wastes. This will also increase the burden on streams receiving untreated sewage.

With the prospect of this progressively increasing load it must be recognized that the quantity of stream flow in summer remains generally static from year to year so that the only method of alleviation is by treatment of the wastes rather than dependence on dilution. It is also unfortunate that the period of minimum stream flow is coincident with the period during which the heaviest seasonal waste loads are discharged. Controlled flow through the operation of impounding reservoirs upstream will afford some measure of relief, but this may be partly offset by large scale irrigation developments.

3. **Present extent of treatment.** At the present time only three of the smaller cities of the Willamette Valley are employing sewage treatment. These are located on small tributary streams. The remaining cities are discharging raw sewage directly or indirectly into the Willamette River.

A minority of the industries are at present giving partial treatment to their wastes. This, for the most part, consists of rough screening of readily removable solids. The greater part of their wastes are still discharged directly or indirectly into the river drainage.

In addition to the pollutional influence of industrial and human wastes the contamination resulting from discharge of untreated domestic sewage deserves special consideration. Human wastes have a high bacterial content, some of which are pathogenic in character. The problems of using contaminated streams for domestic water supply are seriously increased and there are also definite hazards in using such streams for the irrigation of crops and vegetables.

As the dissolved oxygen available in the river decreases the anaerobic bacterial forms increase in number and the aerobic bacteria decrease. When the oxygen is practically depleted, the river becomes septic giving rise to foul and malodorous conditions. Its natural biological balance is distorted to the detriment of the indigenous aquatic flora and fauna. Fish life in the river is seriously affected by this change of environment and game fishes which require a high oxygen content are the most affected.

A further disturbance of the stream condition is caused by the deposition of the sewage settleable solids along the bed of the river. These solids accumulate on the bottom, slowly take up oxygen from the overlying water, and ferment. In some instances these sludge deposits are scoured from the bottom, but in relatively quiescent water they remain until such time as fermentation becomes sufficiently rapid to produce gas which causes the sludge to rise to the surface where it is slowly carried downstream. These bottom sludge areas change temporarily or permanently the physical and biological characteristics of the river in areas where they accumulate, and have a drastic effect on the fish life of the stream by destroying the food organisms and spawning beds.

4. **Results of continued neglect.** Accumulative results of discharging untreated domestic and industrial wastes into a river over many years can be summed up as follows:

a. Oxygen depletion giving rise to insanitary and foul conditions with incipient danger to health when a stream is used for recreational purposes.

b. Economic loss as a potential source of domestic water supply, since communities feel that they are forced to develop remote, inadequate, and uneconomic supplies rather than risk the use of a more plentiful and accessible source known to be contaminated.
c. Increased cost for industrial supplies because of degree of treatment required.
d. Destruction of game fishes and their breeding grounds.
e. Introduction of a health hazard through the use of water containing human contamination for irrigation.
f. The monetary loss due to depleted realty values. This is an aspect of the problem not frequently considered in stream pollution, but currently becoming a matter of public concern and indignation.

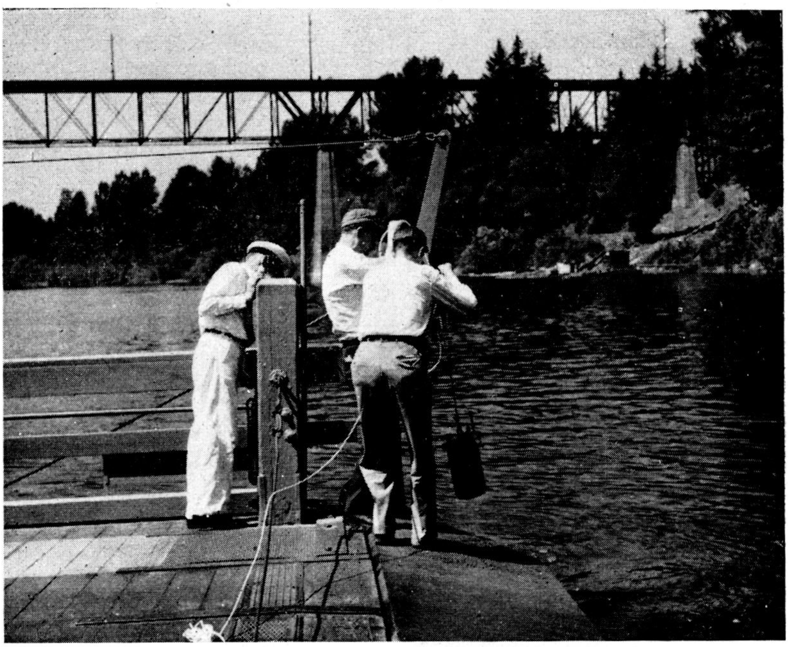

Figure 3. SAMPLING RIVER FROM FERRY AT WILSONVILLE.

5. **Economic aspects.** The general problem of stream pollution is of such significance that all sections of the country are seriously concerned over the common practice of dumping the wastes of human activity directly into rivers. Sewage treatment has been the answer in many parts of the world and the problem in Oregon is recognized by the state itself as expressed in its laws and by increasing interest of the general public.

This interest has led to a demand for a study of prevailing conditions in the streams of Oregon and of the contributory wastes affecting them. This study supplements and amplifies the previous work done by the Engineering

Experiment Station in 1929-36,[1] and in addition explores the character of domestic and current industrial wastes. It has been confined to the Willamette River and sections of the Columbia River Basin since many cities and some industries recognized that if the Willamette River was to survive as a river, functioning for the best interests of all, sewage treatment and sanitary waste disposal were an urgent necessity.

The data compiled from this survey are essential as a basis for adequate design of treatment plants since local conditions affect both the quality and quantity of the waste load to be handled.

Cities outside the Willamette Valley wished the study to be extended to them, since sewage treatment was a part of their postwar plans. Accordingly, the project was expanded to include three eastern Oregon cities.

Time and the physical distances involved precluded the possibility of including the coastal area in this study. It is hoped that this section and a few Willamette Valley communities not prepared to enter the present survey may be served by subsequent surveys.

IV. SAMPLING AND ANALYTICAL PROCEDURES

1. **Sampling in general.** The general problem of obtaining representative sampling is inherently difficult. For example, one would not form an estimate of the climate of a town by a single day's sojourn; neither would one form an opinion of its citizenry by the casual conversation or observation of some of the people on one street at any given time of day, nor would one be justified in judging the character of the town by a trip through one section of it.

With these inherent difficulties in mind it was determined that the sampling for this study be based on the most logical, comprehensive, systematic, and practical methods.

2. **River sampling.** The problem of river sampling could be attacked in three ways: (1) concentrated sampling of the cross section of the river throughout a twenty-four hour period at numerous points along its course; (2) concentrated sampling of the cross section of the river throughout a twenty-hour hour period at numerous points along its course at intervals of time calculated to approximate the rate of river flow; (3) spot sampling at numerous points along the stream once a day at frequent intervals throughout the survey.

The second method, while theoretically the most desirable, was not feasible with the time and money available. The first method was employed on the 1929-30 survey and established the general adequacy of the third method. For this reason and because a better picture could be obtained over a period of time of the general condition of the river throughout the period of diminishing flows, the third method was adopted.

All stations of the 1929-30 survey were sampled at least once. Stations deemed most critical were periodically sampled throughout the duration of the survey. Additional samples were taken on the main river at these stations and on tributaries as supplementary data. Part of the periodic stream sampling was carried on by the field assistants on their routine collection of city sewage

[1]Bulletin No. 6. A Sanitary Survey of the Willamette River from Sellwood Bridge to the Columbia, by G. W. Gleeson, 1936. Oregon State Engineering Experiment Station. Bulletin No. 7. Industrial and Domestic Wastes of the Willamette Valley, by G. W. Gleeson and F. Merryfield, 1936. Oregon State Engineering Experiment Station.

samples. Routine sampling was carried on by the field biologists, field engineers, and cooperating agencies.

The spot samples were taken at the stations in the main current and at approximately one-half depth. Record of river temperature, river condition, time of day, and other pertinent data were kept on a standard form (see Appendix A). Samples were taken with a standard type sampler in which water was washed through the collecting bottles. Two 275 ml bottles were used to collect the water for the dissolved oxygen and the BOD tests. A 100 ml sterile bottle was used to collect the sample for the bacteriological tests. Gallon samples were taken in addition at those stations where pollution was known to be high. The dissolved oxygen samples were set immediately. The Winkler method was used for the fixing of the dissolved oxygen sample and all were transported to the laboratory by the most expeditious means.

3. **Sampling of city sewages.** The variability in the quality and quantity of domestic sewage throughout the hours of the day, and from day to day throughout the year, necessitated a standard method of sampling procedure. A true sample would be a continuous sample in proportion to the rate of flow. Since this is practically impossible, an approximate method was developed and outlined in detail for all cities so that standard conditions would prevail throughout the survey. Mimeographed directions given to the city engineers are reproduced in Appendix B.

Hourly composite samples in proportion to the rate of flow were taken over a twenty-four hour period. Record of location, date, time, depth of flow, location and size of sewer, air and sewage temperatures, weather conditions, and general remarks were kept by the sampling crew on a standard form (see Appendix C). The composite sample was kept at a low temperature by the use of ice and insulated boxes. The composite samples were picked up by the field assistants, transferred to five-gallon milk cans housed in insulated ice boxes in the truck. Ice used by the cities was salvaged for use in the collecting truck. The samples were then transported to the laboratory with minimum delay, where certain tests were performed immediately.

In order to obtain an adequate representation of each city's sewage and at the same time to conserve transportation and labor, the Willamette Valley was divided into three geographical zones and a staggered schedule was set up so that 21 days of representative sewage would be collected from each city during the period of low river flow. Toward the end of this period a second schedule was set up for wet weather sampling once a week on staggered days.

In order to discuss the survey and to demonstrate necessary sampling techniques a meeting was called by the Engineering Experiment Station through the League of Oregon Cities for July 26. Each city over 500 population not having a sewage treatment plant was invited to send a representative to Oregon State College. Unfortunately, all cities contacted were not represented at the initial meeting. The schedule called for sampling to start July 30. The first samples were brought to the laboratory July 31.

The sampling of the sewage in the eastern Oregon cities participating in the survey was carried on in a similar manner except that twenty-four hour composite samples were taken daily for one week. This schedule was arranged to make possible the use of a mobile laboratory loaned by the Oregon State Board of Health.

4. **Sampling of industrial wastes.** Water borne wastes from industrial plants are discharged continuously or periodically. Continuous line processes

usually discharge wastes fairly uniform in quality and quantity whereas batch dumping furnishes wastes of wide variability. Spot sampling of the former for quality analysis is indicative of the character of the waste. In the batch process water is generally used for washing so that composite samples must be drawn throughout the dumping period. Few plants, if any, are strictly of one type; therefore, it is usually necessary to take a composite of a series of composite samples. This type of sampling is difficult to do and expensive of time and money, particularly when it is necessary to make flow measurements at the same time. Rarely is it possible to do this because of the arrangement of the disposal system in the plant and the lack of inspection ports or manholes. Samples of industrial wastes were taken wherever possible to achieve an approximate representation of the plant's operation.

5. **Laboratory tests.** The terms used in the following tests are in the accepted language of the sanitary engineer. It is impossible to avoid them without losing the value of the subject matter. The tests and terms are redefined in language as nontechnical as is consistent with precise statement. These tests were made daily throughout the survey and conclusions are based on their results. In view of the anticipated frequency with which these terms will be used, it is felt that it will be well for interested readers to gain a comprehension of their meaning.

The purpose of making laboratory tests of the rivers and the wastes discharged into them was to identify and evaluate the river condition and the strength and character of the wastes disposed. It should be held in mind that the test results are indicative but not absolute.

The chemical tests applied to river samples were dissolved oxygen (DO), biochemical oxygen demand (BOD), and hydrogen ion concentration (pH). Temperature of each river sample was measured at the time of sampling.

The chemical tests applied to sewage and industrial waste samples were BOD, pH, alkalinity, acidity, chlorides, grease, and the solids determinations, total, volatile, suspended, dissolved, and settleable.

6. **Dissolved oxygen.** Measurement of the dissolved atmospheric oxygen (DO) in water was determined by the standard Winkler method. Examples of the amount of atmospheric oxygen available in pure water are shown in Table 1.

Table 1. RELATION OF DISSOLVED OXYGEN IN WATER TO TEMPERATURE.

Temperature *Degrees F*	Dissolved oxygen *ppm*
32	14.62
41	12.80
50	11.33
59	10.15

The amount of dissolved oxygen present in water is best expressed in terms of weight. The symbol ppm indicates the number of pounds of oxygen present in one million pounds of water. It will be noted that dissolved oxygen decreases rapidly with an increase in temperature of the water. This fact is of great significance in connection with the river condition during summer and fall.

7. **Biochemical oxygen demand.** The term biological oxygen demand will hereafter be used in the customary abbreviation BOD. The BOD is the

amount of atmospheric oxygen used up by a measured volume of waste or water in the biological and chemical oxidation of the organic matter in the waste or water. It is determined in the laboratory by excluding the atmosphere and incubating the sample at a constant temperature for a definite period of time.

If the waste or water is known or presumed to lack sufficient dissolved atmospheric oxygen to carry on the oxidation process, standard saturated dilution water is added in known amounts more than to supply the deficiency.

The dissolved atmospheric oxygen of the waste or the diluted waste is measured immediately and at the end of five days incubation at 20 C. The difference in these two values corrected for the necessary dilution is the 5-day BOD and is expressed in parts per million (ppm) by weight. This 5-day BOD represents approximately 68 per cent of the 20-day BOD necessary for practically complete oxidation.

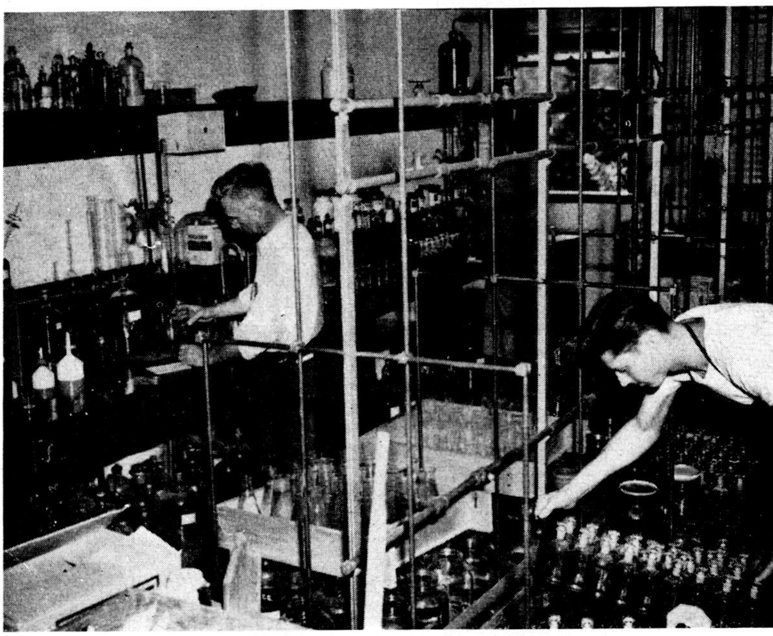

Figure 4. LABORATORY ANALYSIS OF RIVER SAMPLES.

This 5-day test is commonly employed because it is practical and economical. It is the best indicator of the relative organic strengths of various wastes and of their probable effect when discharged into the receiving stream.

The BOD of a river at any point indicates the amount of dissolved atmospheric oxygen needed to oxidize the wastes in the river at that point during the next five days. It does not represent the total amount of oxygen for complete stabilization. It has been well established that 5-day BOD represents 68 per cent of the total demand for stabilization and that the 20-day BOD represents 99 per cent of the total demand. For laboratory economy and convenience 5-day BOD's were made on the river samples and the results were corrected for 20-day BOD. It is necessary to use a 20-day BOD figure because it was found in 1929 that the river required in excess of 20 days to flow from Cottage Grove to the Columbia.

The term BOD is of extreme importance in the classification of sewages and rivers and the following examples will serve to illustrate its use.

A domestic sewage with a BOD of 50 ppm or 50 lb oxygen required for 5-day oxidation of 1,000,000 lb of sewage would be considered a weak sewage, whereas one with a BOD of 500 ppm would be considered a strong domestic sewage, whose strength would be approximately 10 times the former.

Industrial wastes usually have higher BOD's than the stronger domestic sewages, as is illustrated in Section V.

A direct example, omitting modifying factors, is given to illustrate the use of the term when applied to the river. Assume a river has a dissolved oxygen content or DO of 8 ppm and a BOD of 2 ppm. The DO in the river five days downstream would be 6 ppm except for additions of tributaries, other wastes, and reaeration if the temperature were 70 F.

A river must have enough DO or receive enough DO from downstream tributaries to support its own and the tributaries' BOD and the BOD of all wastes discharged into the river below that point. This can be illustrated in the following manner:

Assume that at a certain point on a hypothetical river the flow is 1,000 cubic feet per second. The DO is 8 ppm and the BOD is 2 ppm. At this point a sewage made up of domestic and industrial wastes with a flow of 2 cubic feet per second and a BOD of 1,500 ppm is discharged into the river. The approximate dissolved oxygen required during the next 5 days while the river is flowing downstream, and the approximate DO available at a point 5 days downstream can be computed in the following manner, disregarding the effect of reaeration. Total atmospheric oxygen in the river is 43,200 lb. The oxygen required in 5 days to satisfy the river BOD is 10,800 lb. The oxygen required in 5 days to satisfy the BOD of domestic and industrial waste is 16,200 lb. The oxygen available in the river 5 days downstream from the initial point is 16,000, or 3 ppm. Under actual conditions a river receives wastes and its volume is increased by tributaries throughout its course. Dispersed wastes from farm and rural areas add to the burden of the stream. The strengths and volumes of the latter are indeterminate.

8. **pH.** The symbol pH is mysterous only in its typographic appearance. It is always followed by a number ranging from 0 to 14. The combined symbols represent the intensity of acidity or alkalinity of a substance. The symbol is read p-H. A pH of 7.0 is neutral. At this point the intensities of acidity and alkalinity are equal. A pH of 6.0 has an intensity of acidity 10 times that of neutral or pH 7.0. A pH of 5.0 has an intensity of acidity 100 times that of neutral. Likewise a pH of 8.0 has an intensity of alkalinity 10 times that of neutral, and a pH of 9.0 has 100 times the intensity of alkalinity as neutral. Table 2 illustrates the range of intensities.

The greater numerical distance the pH of a substance is from 7.0 the greater is the chemical activity and instability of the material. For example, weak sulphuric acid has a pH in the neighborhood of 2.0 while weak lye has a pH of approximately 12. Most natural waters have a pH between 6 and 8. The pH of water may be lowered by the decomposition (slow oxidation) of organic matter or may be raised by solution of mineral salts. The pH can be measured by comparison of color standards employing organic dyes of known strength. It can be measured also very accurately electrically. The latter method is preferable where color of the waste interferes with the color standards. The electrical method was used in all of this survey.

Table 2. HYDROGEN ION CONCENTRATIONS (pH) SCALE.

		Acid range					pH			Alkaline range				
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
10M	1M	100T	10T	1000	100	10	Neutral	10	100	1000	10T	100T	1M	10M
	Times intensity of acidity									Times intensity of alkalinity				

Note: M=Million. T=Thousand

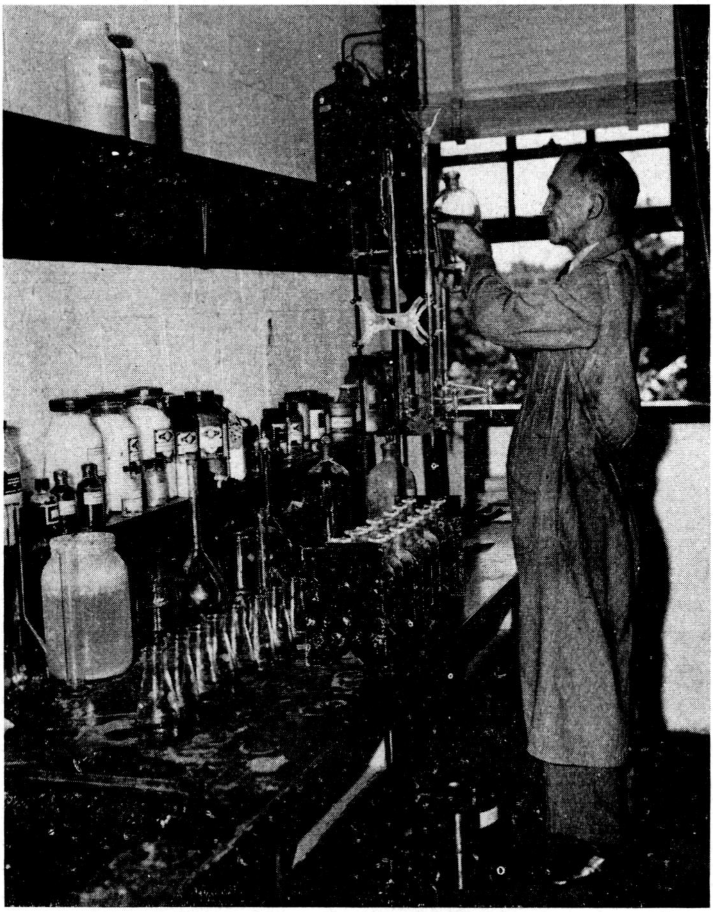

Figure 5. ALKALINITY DETERMINATIONS.

The pH of a stream may be an indicator of certain conditions in the river and the pH of sewage indicates the stage of decomposition of the sewage. It is also used as a control device in sewage treatment operations.

9. **Alkalinity and acidity.** Alkalinity and acidity tests, as differentiated from pH, are standard tests made by neutralizing the sample with standard solutions of acid or hydroxide in the presence of indicators. The tests indicate the amount, and not the intensity, of alkalinity and acidity, and are expressed in ppm of calcium carbonate. They are particularly useful for tracing sources of extraneous waste. Discharge of concentrated acid or alkaline wastes may seriously disrupt treatment plant functions.

10. **Chlorides.** The colorometric test for chlorides was used for many years as an index of human contamination on drainage areas. Its value in sewage tests is in pointing out the natures of some industrial wastes. Discharges of large volumes of brine, for example, may seriously affect sewage treatment operation.

11. **Grease.** The standard test for grease in sewage is not satisfactory and results on the sample are difficult to duplicate. The test is time-consuming and production methods on many samples cannot easily be achieved since highly combustible materials are used in the test. At first it was hoped to run tests by a nonstandard method devised by H. W. Gehm. Tests were run by this method, though not on all samples, since this test, while simpler, was still complicated and time-consuming.

Grease in sewage originates from several sources: kitchens, garages, dairies, hotels, and some industries. Most cities have ordinances requiring grease traps for garages and service stations, but enforcement is lax. The practice of dumping crankcase drainings and swilling the floor of garages with solvents is common in many places. Odor of gasoline was particularly pronounced in some sewers and hazardous conditions were noted in several manholes.

Grease in sewage varies considerably in the same town and the problem of its removal is one that should be solved in the design and operation of the plant. Oil slicks are visible at the end of many sewers discharging into the rivers. Sources of such oil dumping can be traced by an alert city force and drainage access to city sewers withdrawn.

12. **Solids.** The results gained from these tests are basic to the design and operation of sewage treatment plants. Solids are classified as total, volatile, suspended, dissolved, and settleable.

13. **Total solids.** A measured standard volume of a sample of sewage or waste is evaporated to dryness at 103 C in a precisely weighed dish. After cooling the dish is again precisely weighed; the difference represents the total solids in the sample and is expressed in ppm.

14. **Volatile solids.** The dish and sample used in determining total solids are placed in an oven and calcined. After cooling the dish is precisely weighed again and the loss in weight measures the volatile solids in the sample, also expressed as ppm.

15. **Suspended solids.** A measured volume of sample is vacuum filtered through a dry asbestos mat supported in a standard Gooch crucible and dried.

The weight of the crucible with its content is precisely determined before and after the filtering. The increase in weight is expressed in ppm as suspended solids.

16. **Dissolved solids.** The difference between the total solids and the suspended solids shown above is expressed in ppm as dissolved solids.

17. **Settleable solids.** One liter of a sample of sewage or industrial waste is allowed to settle in a graduated glass cone known as the Imhoff cone. After two hours the amount of settled material is read directly in milliliters per liter.

18. **Bacteriological tests.** Bacteria and related forms of life are part of the normal flora and fauna of any river. They serve as agents of organic decomposition. The number of bacteria grown on nutrient agar is used as an indicator of the pollutional load. The presence of such bacteria in excess of established standards, prohibits the use of such water as a source of water supply or for recreational purposes.

The presence of anaerobic forms in large numbers is an index of oxygen depletion and is recognized by noxious odors. Foul gases are produced by these particular bacteria while the aerobic forms generally produce inoffensive end products. Domestic sewages introduce into a stream enormous numbers of both forms along with the pathogenic organisms that are responsible for typhoid and dysentery. In general, bacteria die rather rapidly in unpolluted streams, largely due to unsuitable environment. In polluted waters ample food supply is available and the bacterial population, other things being equal, multiplies rapidly.

It has previously been established that all domestic sewages contain high concentrations of bacteria. The intestinal tract of man and animals contains a high proportion of bacteria. A large number of these bacteria are known as E Coli. The presence of E Coli group in a sample of water indicates contamination by animal or human fecal matter.

No extended bacteriological examinations were made on raw sewage wastes. Confirmatory examinations were made to determine that the sewage wastes were comparable with the findings in other locations. The value of such tests on sewage is in the operation of treatment plants where an essential function of the plant is the large reduction of bacterial population. Bacteriological examination of the river samples was made throughout the survey.

19. **Total bacterial count.** The numbers of bacteria were determined by count on samples of domestic sewage grown on nutrient agar plates at 37 C for twenty-four hours.

20. **E Coli.** The mean probable numbers of E Coli were determined by the standard method of growing in lactose broth fermentation tubes samples and diluted samples. Presence of gas-forming organisms constituted tests. Samples from these tubes were partly confirmed by standard brilliant green bile.

21. **River flow measurements.** Measurements of the rate of flow of rivers and sewages are an essential part of any stream pollution survey. It has previously been mentioned in Section III that volume of flow of a river is a major characteristic. Quantitative measurements were made available through the office of the U. S. Geological Survey in Portland. Gage heights on the Willamette and its tributaries are read daily by this organization and from

predetermined rating curves the daily flow is computed. While the gages were not located at sampling stations the flow at the gaging stations reflected the flows at the sampling stations.

22. **Sewage measurements.** Sewage varies in both volume of flow and quality continuously throughout the day and night, as an examination of the flow records in the results will show. The flow not only varies throughout the day but also from day to day throughout the season. During the summer and fall the change in flow from day to day is usually not large. The variation during winter and spring, however, may be very large, dependent, of course, on whether street and roof drainage are carried by the sewerage system. Also, sewers poorly constructed or broken down through length of service or traffic loads will carry off in winter and spring ground water that is close to the surface.

The actual measurement of sewage flowing in sewers has always been considered a difficult problem. Most of the difficulties are not insurmountable when care and consideration are given to their individual solution. Since data concerning the rate of flow are essential to economical and efficient design of sewage treatment plants and trunk sewers, it is well worth while to spend considerable time and energy to obtain such records.

Measuring devices such as weirs and flumes must be calibrated for the particular sewer. Recording instruments are the only practicable means of registering the flow over the measuring device. These instruments can be furnished with a special attachment at a nominal extra cost to record the actual flow in gallons per day or cubic feet per second. The value of this attachment cannot be overestimated since tedious office computations are eliminated. The device pays for itself many times over and the whole recording instrument later becomes a part of the sewage treatment plant. Attempts by the authors to obtain flow without measuring devices and recording instruments involved a disproportionate amount of time in the field. Long tedious hours of office calculations could have been avoided if most of the cities had promptly installed these devices when advised to do so at the beginning of the survey.

Instruments to record the depth of flow through a measuring device have presented a difficult problem to instrument manufacturers. The inside of a manhole is very moist and this humidity affects the paper on which the heights are recorded. Confronted with this problem in 1939-40 a celluloid sheet was used in place of paper on a standard recording instrument in the Corvallis sewers by Mr. Charles Willey and the senior author. The roll was removed at the end of the weekly period and placed over graph paper and blueprint paper. A blueprint made from this gave an excellent chart of the measurement. The celluloid sheet was washed clean and returned later to the instrument for reuse. By this method items of absorption, the pen sticking in soft places on paper, and blurred records were eliminated. Extreme accuracy is not as essential as reliability of operation and clarity of record.

No city except Pendleton had measuring or recording devices installed in sewers at the time the present survey was begun, and so the problem of quantitative measurement of sewage had to be delayed until pressure of other field work released the authors to make approximations for the cities by the float method.

In the initial concept of sampling it was determined that representative sampling would require that each sample be taken in proportion to the rate of flow. With this in mind calibration strips were made for 18 diameters of sewers and for 4 special shapes. These calibration strips, fastened to the outside of standard glass jars, were used in connection with recorded depths to give proportional flow sampling. These recorded depths later proved to be the only means by which rate of flow could be calculated for a considerable portion of the sewers. In all depth measurements allowance was made for the effect of wave action, but in steep gradient sewers the accuracy of measurement decreased. Slopes of sewers between the sampling manhole and the next manhole upstream were either obtained from the city engineer or were determined by the field engineer.

Figure 6. COMPOSITE SAMPLING OF SEWAGE.

Approximations of flow were made by the use of floats for velocity determination. After many trials apples were used as floats, and surprisingly consistent results were obtained even in the larger sewers. Another method of determining velocity was by use of dye dumped in one shot into the sewage. This method was used where partial clogging of the sewer occurred, but it did not prove to be very satisfactory.

The quantity of flow was computed from the sewage and the float velocity corrected to a mean. By means of the depth, area, and quantity curves for the particular sewer shape, the quantity of sewage when the sewer was flowing full was computed.

The roughness coefficient was determined for this condition at partial depth. Whenever the situation permitted float checks were made at other depths.

Since the majority of industries, not already sampled in previous surveys, possessed neither measuring equipment nor available records of bulk or liquid wastes, float measurements were made where possible.

V. RESULTS AND THEIR INTERPRETATION

1. **River Conditions.** The sampling periods on the river in 1944 were divided into intervals of approximately consistent meteorological and hydrological conditions. The unusual operation of the flood control dams during construction work on the Willamette River and tributaries introduced some discrepancies from the normal. Normal operation of the release of stored waters behind these dams will probably improve the river conditions, but since these operating characteristics and their effects are unknown, the river will be considered on the data as found. The intervals of time chosen were:

From August 13 to September 12, 1944
From September 13 to October 12, 1944
From October 13 to October 31, 1944
From November 1 to December 5, 1944

December 5, 1944 was the official closing of the survey; however, because of the importance of the work, sampling at critical stations was and is being continued at bimonthly intervals to extend the record through the entire year. The same general weather and river flow conditions existed throughout the drainage area in the summer and fall of 1929 and 1944.

In what follows Table 3, which is a partial tabulation of Figure 9, and Figures 10, 11, and 12 are interpreted for the main river from its source to Portland.

Above Cottage Grove there was no evidence of any change in the overall conditions of the river since 1929.

Below Cottage Grove the DO and its saturation remained practically unchanged. The BOD showed perceptible increase, however, and the river was definitely more contaminated. Just above Springfield the DO and its saturation were practically unchanged. Similarly the BOD and the contamination remained the same.

Between Springfield and Eugene there was a definite decrease in the DO and saturation. The BOD was almost identical for the two years. The contamination by E Coli has increased.

Table 3. COMPARISON OF THE AUGUST 1929 AND AUGUST-SEPTEMBER 1944 PERIODS.

Location	DO		20-day BOD	
	1929	1944	1929	1944
Above Cottage Grove	8.8	9.5	1.5	1.6
Below Cottage Grove	7.9	7.7	1.8	3.3
Above Springfield	8.8	8.4	0.9	0.7
Below Springfield	9.2	8.4	1.0	0.9
Below Eugene	8.6	7.8	1.4	2.7
Peoria	9.0	8.7	0.7	2.7
Below Corvallis	8.6	8.1	0.8	2.8
Independence	8.7	7.7	1.8	2.2
Wheatland below Salem	6.9	5.9	3.4	6.5
Newberg	6.9	4.4	2.0	3.0
Wilsonville	5.1	1.5	2.0	12.3
Willamette	4.4	1.0	1.4	9.0
Below Oregon City	4.8	2.1	4.5	12.6

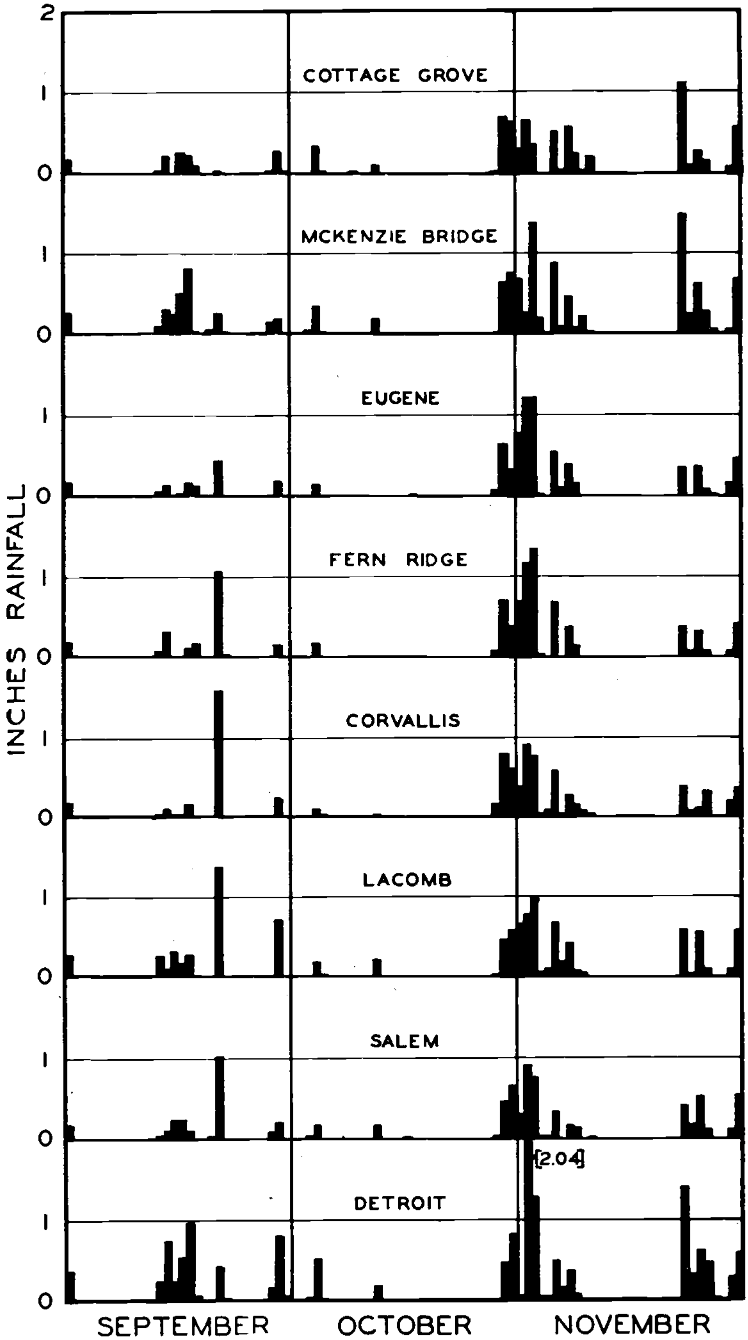

Figure 7. Rainfall in Willamette Valley, 1944.

Three miles below the Eugene outfall sewer and above the confluence of the McKenzie the DO and saturation dropped sharply in 1944. The BOD increased more rapidly than the DO decreased. This can definitely be attributed to increased domestic and industrial wastes compared with 1929. The major industrial waste that changed in this period was due to the large cannery which dumped untreated wastes into the city sewer. From August to December 1944 the river was discolored by the large volume of beet waste for a distance of a half mile below the sewer outfall. Deposits of sludge lined the west bank for more than a quarter mile. The sewer discharged at the river's edge during low water periods, furnishing no opportunity for mixing with the river.

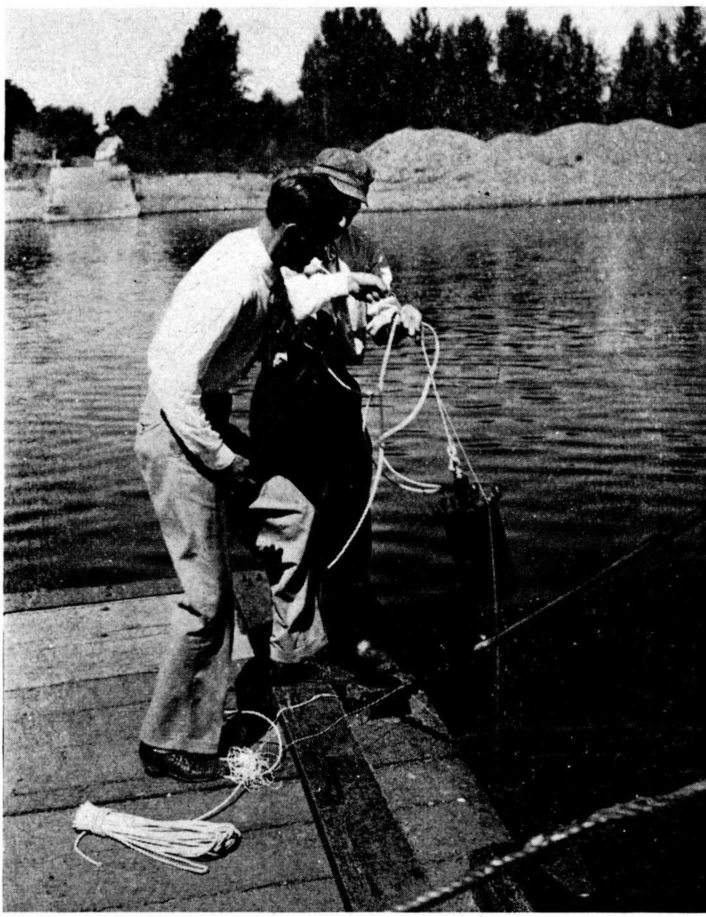

Figure 8. RIVER SAMPLING AT WHEATLAND.

During the first sampling interval of the survey considerable construction work was in progress for several miles on the Long Tom river. This work may largely be responsible for the high BOD at Peoria. However, a large flax retting plant located on the Long Tom near Monroe lagooned its untreated retting waste in the Long Tom river channel. The drainage from this lagoon would seriously add a considerable burden to the main stream. Straightening of the river channel in this area prevented adequate representative sampling of the Long Tom itself.

There was at Peoria a similar decrease in the DO and saturation. The contamination was higher than in 1929.

One mile below Corvallis there was a slight and consistent decrease in the dissolved oxygen and saturation in 1944 compared with 1929. The BOD showed considerable increase similar to that at the Peoria station.

No regular sampling was made between Albany and Independence on the Willamette River though regular sampling was carried on at Jefferson on the Santiam River. The dissolved oxygen at Jefferson was the same in 1944 and the BOD was slightly higher. The Santiam was more contaminated.

At Salem in 1944 the river entered the city with an adequate DO but a decreased saturation. The BOD of the river increased from 1929 to 1944.

Thirteen miles below Salem at Wheatland the DO and its saturation value showed evidence of sharp decrease while the BOD was higher than the DO and was almost doubled in the fifteen year period. Similarly the contamination at Wheatland was considerably in excess of 1929.

Just above the Newberg waste and sewer outlets the DO was just below 5 ppm which is 2 ppm below the 1929 figure. The saturation of oxygen showed similar decline. The river at this point, from the few samples taken, showed gross contamination.

At Station 23, Wilsonville, approximately twelve miles below Newberg, the average DO was less than 1.5 ppm and in three instances showed complete exhaustion of the oxygen. The average saturation was nominal, while the average BOD was in excess of 12 ppm. The river at this point was simply an enormous sewer. The contamination from bacteria in spite of the antiseptic action of sulfite liquor from the Newberg pulp mill was severe.

At the town of Willamette below the junction of the Tualatin and above the Oregon City Falls, the per cent of oxygen saturation was 10, which is negligible, and the DO had decreased 3.5 ppm since 1929. The BOD increased during this period more than 7.0 ppm.

Just below Oregon City the DO decreased from 4.8 ppm in 1929 to 2.2 ppm in 1944. The saturation value was about 23 per cent. The BOD increased from 4.5 ppm to 12.6 in 1944. The effect of tidal action at this point was not investigated. Results of such tidal effects were determined by Gleeson in 1936 and published in Engineering Experiment Station Bulletin No. 6 already referred to.

The contamination of the river at Oregon City was severe.

The condition of the river entering Portland was considerably worse in 1944 than in 1929. The saturation of DO was less than 10 per cent and the BOD on the few tests made was far in excess of the oxygen available.

2. **1944 and 1929 comparison.** A comparison of the river, in more general terms, in August 1929 and in August and September 1944 is presented in the following discussion.

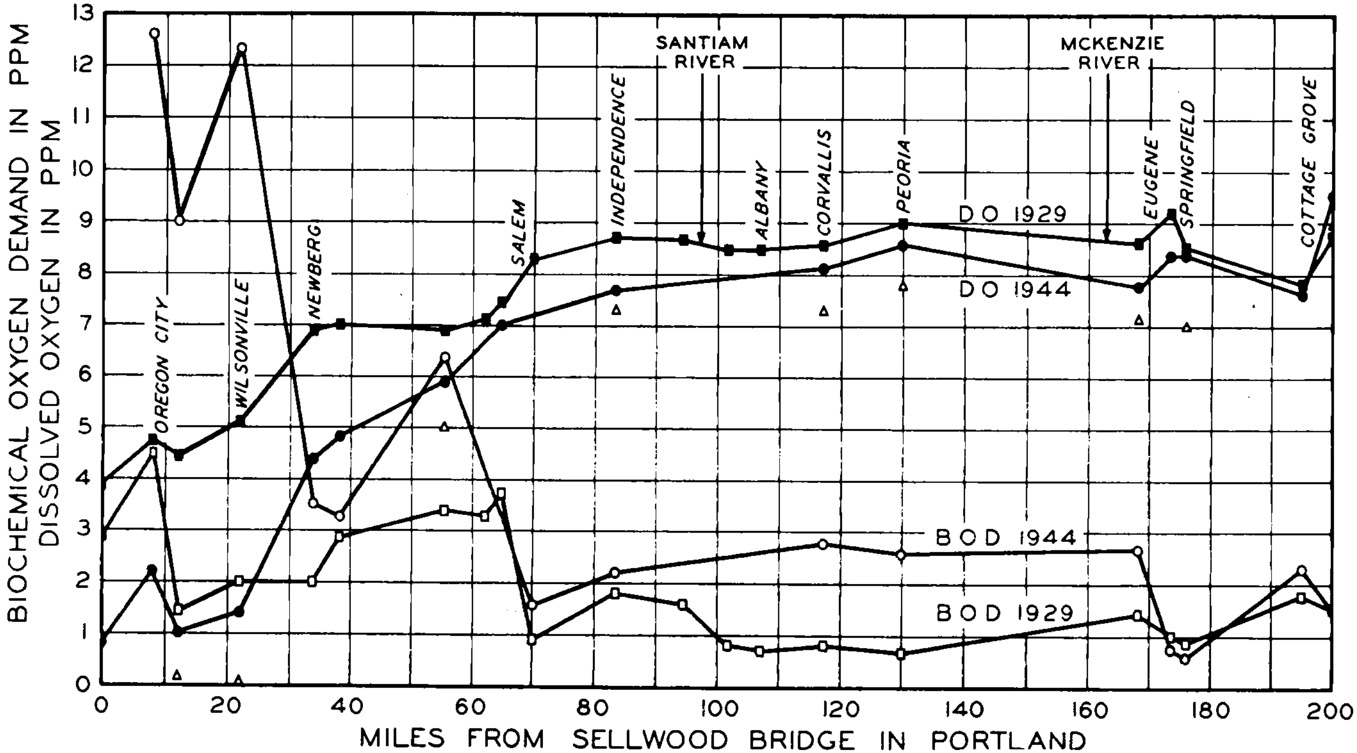

Figure 9. Oxygen Content and Pollution of Willamette River. August 1929 and August-September 1944.

From a point above the Cottage Grove dam to Springfield the dissolved oxygen and the saturation of oxygen remained practically unchanged. The effects of sewage wastes from Cottage Grove were still apparent. The increase in BOD can be attributed in part to the increase in industrial activity in that area. The river was not seriously contaminated except immediately below Cottage Grove.

The river entered Springfield with high DO content, well saturated and with less than 1 ppm BOD which showed little or no difference existing between 1944 and 1929. The effect of reaeration between Springfield and Eugene was not noticeable in 1944 in the DO. This might have been due to the rapid oxidation of the flax retting wastes discharged from the Springfield plant.

The effects of the Eugene domestic and industrial sewages are noted in the decrease of the DO and the sharp increase in the BOD. In addition the river was severely contaminated in 1944. This section below Eugene was the most highly contaminated part found in the whole survey. This was logical since the pollutional load was large in proportion to the flow. From this point downstream to the mouth the DO curve of 1944 drops below the 1929 curve. Correspondingly, the BOD curve of 1944, except for one minor irregularity, diverges and exceeds the 1929 curve at every sampling point.

The influence of the McKenzie River is indicated by the improved DO content at Peoria and Corvallis. The BOD however remained constant to Peoria, probably due to the previously mentioned construction on the Long Tom and the flax plant at Monroe.

The BOD below Corvallis was augmented by domestic and industrial wastes. The contamination of the river was low at Peoria but noticeably increased with the addition of Corvallis sewage.

The effect at Independence of the Santiam River, whose south fork was heavily polluted by pulp mill and cannery wastes from Lebanon, was detrimental to the general condition of the river. Increased industrial activity in Albany was of course a contributing factor. A meat packing plant just outside Albany discharged untreated wastes into a small tributary stream. The condition of this stream was repulsive. Camp Adair was practically evacuated before the survey began so that the effect of the sewage treatment plant effluent from there was not noticeable.

The effect of the domestic sewage and industrial wastes from the Salem area was pronounced at Wheatland and downstream. The BOD at this point exceeded the DO and the contamination while not as severe as at Eugene was inordinately high. The increase of BOD was more than 4.5 ppm between Independence and Salem in spite of the effects of excellent reaeration between these points.

During the survey in early September numerous cakes of sludge filled with gas bubbles were observed by the field biologists and by the ferryman at Wheatland. The biologists and field engineers traced this material to its source in a branch of the river at the northern outskirts of Salem on the east bank. Fortunately this slough was readily accessible and received frequent inspections and samplings. This sludge, deposited in the slough by the Hickory Street sewer, and possibly by one of the canneries, settled, forming a blanket several inches thick over several hundred square feet of river bottom. Because of the high temperature of the river water (70-74 F) in September the sludge fermented, gas was evolved, but not released, and the sludge slowly rose to the surface and was transported downstream. Samples taken close to the surface

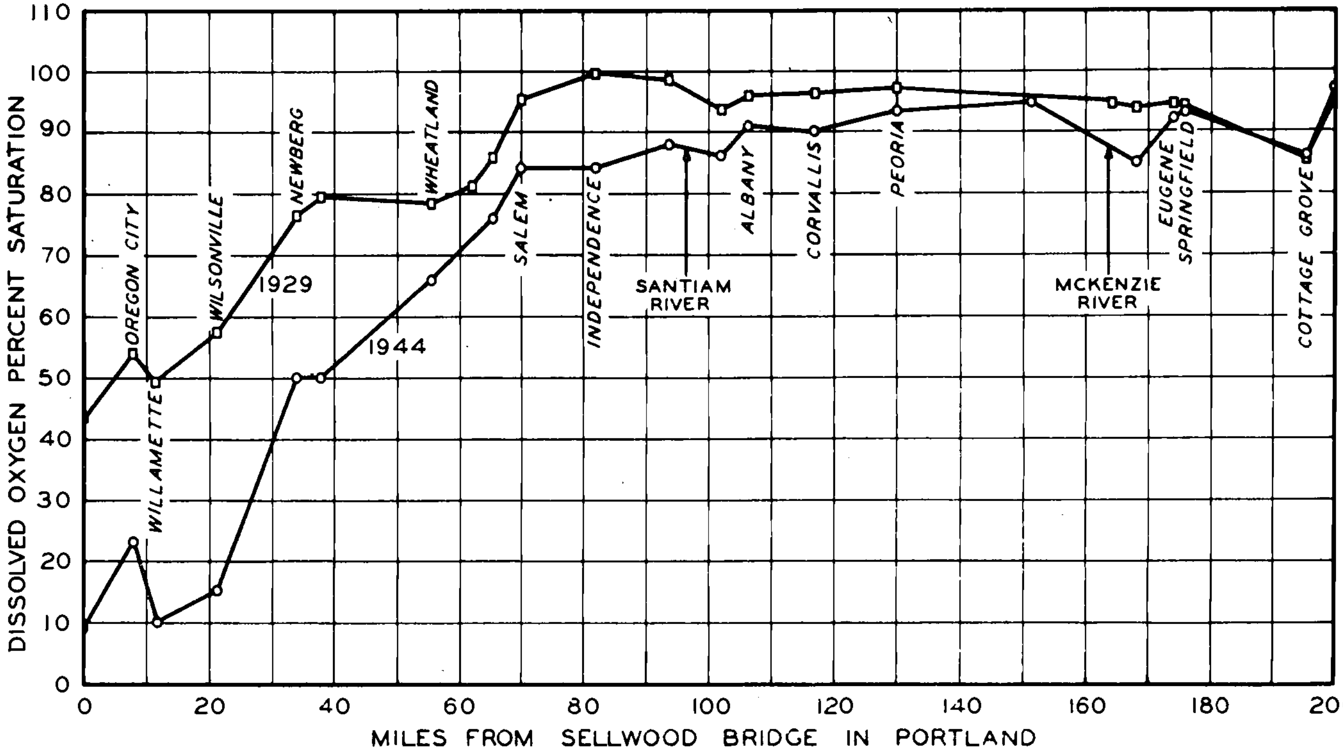

Figure 10. OXYGEN SATURATION OF WILLAMETTE RIVER.
August 1929 and August-September 1944.

of the sludge blanket on October 3, 1944, had a DO of 0.0 and a BOD of 30 ppm. Samples taken in the same position on October 31 had a DO of 4.0 ppm and a BOD of 58 ppm.

The decrease in DO between Wheatland and Newberg was due to the continuous oxidation of the organic load remaining in the river from the upstream wastes previously mentioned and the new wastes introduced by the Yamhill River which had low DO. The BOD decreased between these points due to the reaeration and the small volume of BOD introduced by side tributaries. This scenic stretch of river near historic Champoeg has been expressively described as a biological desert. The justification of this phrase, apart from the biology, can be obtained at a glance from Figure 9. The abrupt decrease in DO and saturation and the precipitous rise of the BOD leave a disparity of 11 ppm in a twelve mile reach of water. The exhaustion of oxygen accomplished in this stretch of river approximately two days' flow time below Newberg carries the stream beyond the point of possible recovery when the industrial wastes of West Linn and Oregon City are considered.

Between Wilsonville and the town of Willamette, the oxygen decreases and the BOD decreases as well, because of the oxidation of the river and the decreased deoxygenation rate.

The effect of aeration by the turbines and dam at Oregon City is shown by an increase of more than 1 ppm in the DO content. The addition of the industrial wastes and the domestic sewage increased the BOD 3.5 ppm.

In recapitulation it can be said that the extremely critical condition that existed at Sellwood Bridge, Portland, in 1929 has now moved upstream at low flow period to a point just below Newberg, a river distance of 30 or more miles. The stream condition by the standard of oxygen content prevailing just below Newberg in 1929 has now progressed to Wheatland, twenty-two miles upstream. The Wheatland condition of 1929 was encountered in 1944 11 miles upstream, just below Salem. The river condition at Salem in 1929 was found at Independence in this survey. This progressive but diminishing pollutional increase was traceable to a point just below the Springfield outfall sewer. Except for approximately 40 miles below the mouth of the McKenzie and above Corvallis on the Willamette River, the river is dangerously contaminated and certainly unfit for recreational purposes. Its commercial value as a water supply has been jeopardized and its use for irrigation and stock rendered dangerous. It can be and is being used as a source of water supply in sections of relatively low contamination, but its employment requires expert operation under competent supervision.

Examination of Figure 12 shows a small but definite improvement in the river during October 1944. The period from September 13 to October 21, 1944, is comparable with the same period of 1929. The effect of dams and increased flow in November 1944 is obvious and the river is further improved as the cold rainy season progresses, seasonal loads decrease, and the activity of the organisms is inhibited. The rate of deoxygenation rapidly decreases with temperature. From September to December the temperature decreases 30 degrees Fahrenheit.

Were it not for the McKenzie River which contributed the major part of the flow in the upper half of the Willamette drainage area, the downgrading influence that was initiated at Eugene would be extended throughout the length of the river to Wheatland. The McKenzie was sampled periodically at Armitage Bridge near Coburg and the lowest DO found was 8.8 ppm and the BOD averaged 1 ppm with most samples below 0.5 ppm.

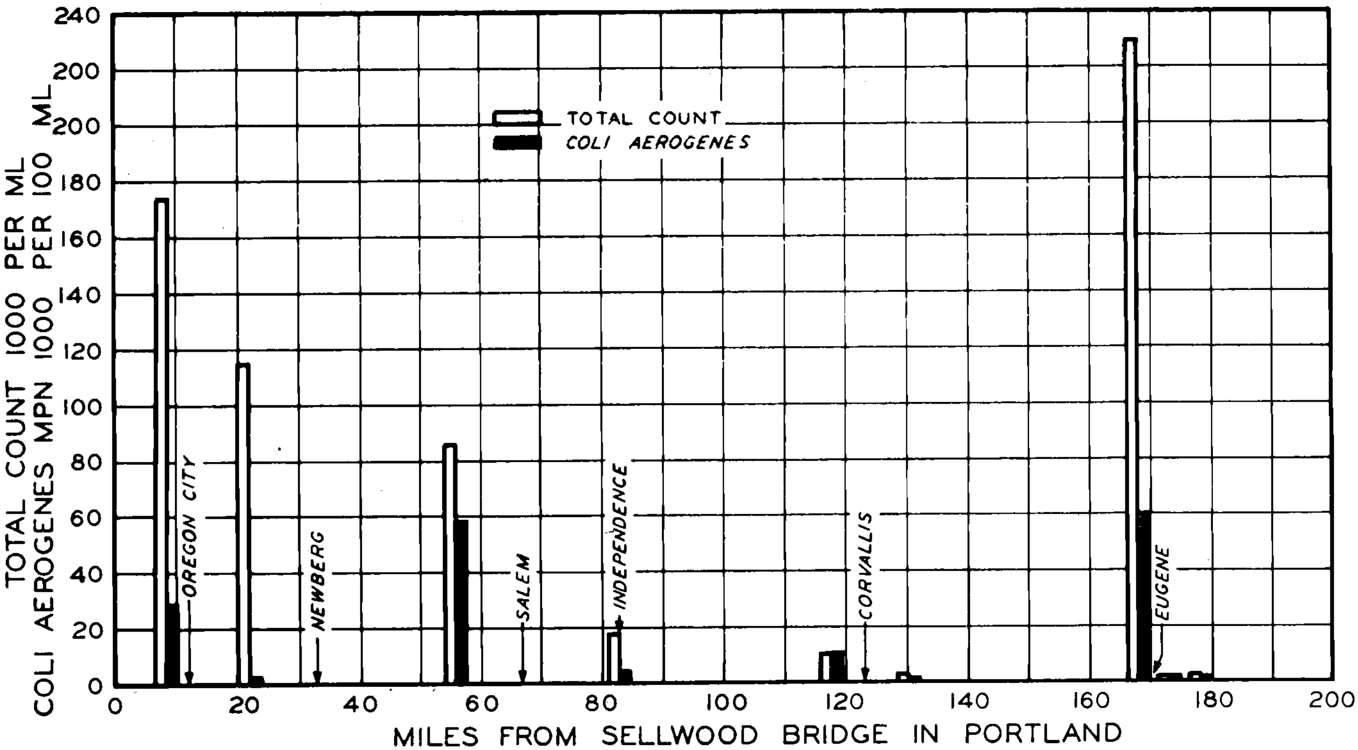

Figure 11. Contamination of Willamette River. August-September 1944.

The South Santiam River was progressively sampled on September 20, 1944, from Waterloo Bridge above Lebanon to Knox Butte and on the main Santiam at Jefferson. Table 4 shows the depletion and recovery of a stream subjected to strong industrial wastes.

Table 4. SOUTH SANTIAM RIVER CONDITIONS, SEPTEMBER 20, 1944.

Location	Miles from Waterloo	DO ppm	Temperature F	Saturation %	BOD ppm
Waterloo	0	9.4	64	98	1.0
Lebanon	7	9.0	65	95	2.2
Brewster	11	3.6	64	38	11.6+
Crabtree Bridge	14	4.6	68	50	12.4+
Knox Butte	22	6.2	66	66	3.4
Jefferson	25	8.2	66	88	2.0

Sampling of the tributaries of the Willamette had of necessity to be only incidental to the main survey. Travel distances involved precluded the possibility of making adequate surveys of the tributaries. Evidence gained from the sampling that was possible was highly indicative but cannot be considered as conclusive.

There is evidence that the South Yamhill, Pudding, Calapooya, and Tualatin rivers, Rickreall Creek, and the stored waters of the Long Tom were deficient in oxygen, and in some cases have a high oxygen demand.

Some of these streams, such as the Rickreall, the Coast Fork of the Willamette, and the Calapooya show evidence of severe contamination.

3. **City sewages.** The cities that participated in the survey and followed a regular biweekly schedule of sampling from July 31 to December 5 are listed in Table 5.

Table 5. SEWAGE SAMPLING SCHEDULE FOR CITIES.

Location	Sewers sampled	Days of sampling
Eugene	1	26
Springfield	1	22
Harrisburg	1	13
Corvallis	4	14
Albany	4	17
Lebanon	1	24
Independence	1	15
West Salem	1	25
Salem	3	22
Mt. Angel	1	4
Sheridan	2	16
McMinnville	3	24
Newberg	4	23
West Linn	4	25
Oregon City	11	27
Gladstone	2	25
Oswego	3	2
St. Helens	1	26

A survey of city sewages was carried on in eastern Oregon for Pendleton, The Dalles, and Hood River, employing the facilities of the mobile laboratory of the State Board of Health. Samples from these cities were taken daily over a period of a week or more.

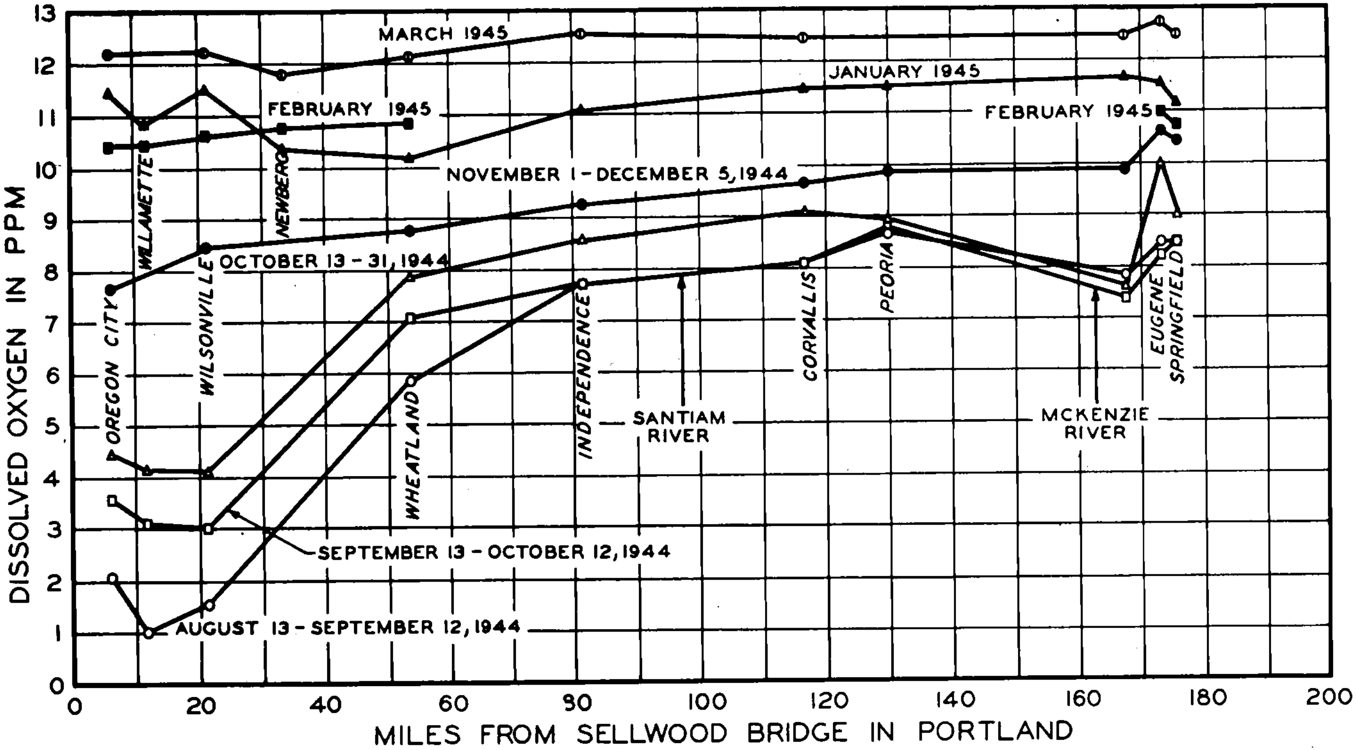

Figure 12. Oxygen Content of Willamette River.

More than 12,000 individual tests including bacterial examination were made. The data were recorded on standard forms which included the hourly depths, temperatures, and weather conditions of the individual samplings. These data are the property of cooperating cities and the State Sanitary Authority, and are not reported in detail in this bulletin.

The qualitative data in connection with the sampling of city sewages were combined into the periods shown in Table 6. A sample of one of the schedule forms is included in Appendix D.

Table 6. WEATHER CONDITIONS FOR VARIOUS PERIODS DURING SAMPLING SEASON.

Period	From	To
Dry and warm	July 30	Sept. 20
Wet warm	Sept. 21	Sept. 21
Dry and cool	Sept. 22	Oct. 28
Dry	July 30	Oct. 28 excl. Sept. 21
Wet and cool	Oct. 29	Nov. 25
Total	July 30	Nov. 25

Because of space limitations only the last period, the total, July 30 to November, is shown in Table 9. Careful examination of this table will reveal the wide variability in quality of the sewages analyzed. These average extremes are summarized in Table 7.

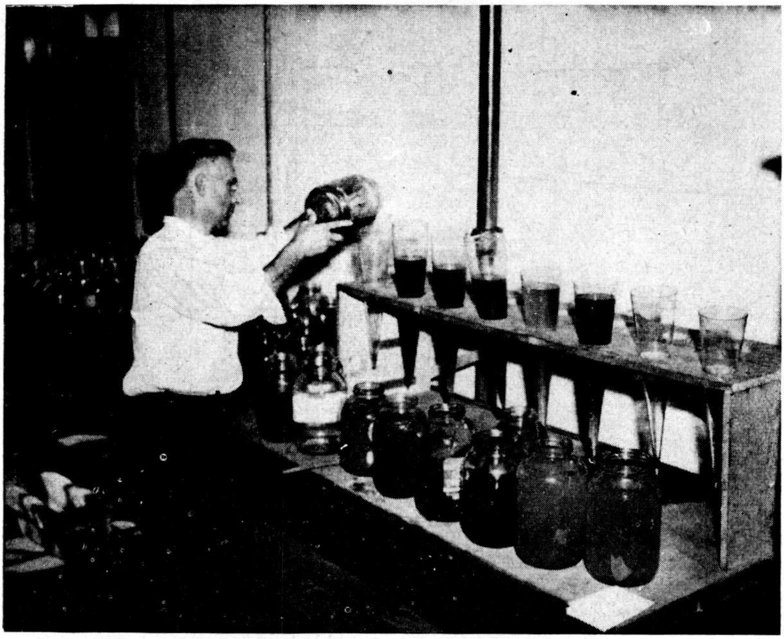

Figure 13. SETTLEABLE SOLIDS DETERMINATION.

Detailed interpretation of these data for each community to the general reader would serve no useful purpose. Recognition of this fact was largely responsible for the holding of a short course at Oregon State College for the participating City Engineers in February 1945. At this course, individual city data were examined by the engineers, State Sanitary Engineer, and the authors with discussion of the problems indicated by their particular data. The city engineers performed the same battery of tests as those conducted in the survey. Following the course in Corvallis an inspection of nine sewage treatment plants in southern Oregon was made to observe first-hand current operational practices.

Table 7. RANGE OF SEWAGE ANALYSIS RESULTS.

Item	Maximum	Minimum
BOD	1,260	10.0
pH	11.5	3.8
Settleable solids	490	0.1
Alkalinity	974	0
Acidity	741	3
Chlorides	280	5
Total solids	6,416	84
Volatile solids	4,325	19
Suspended solids	3,826	8
Dissolved solids	6,270	0
Grease	484	21

Note: All the foregoing figures are expressed in parts per million except pH and settleable solids. The latter is expressed in ml per liter.

Ten recorders and 5 weirs were installed by the cities in a total of 53 sewers during the survey and 4 cities are accumulating quantitative records throughout the year.

Examples of the variation in flows are illustrated in Table 8. Figures are in cubic feet per second. The close correspondence between high flows and rainy weather is the result of infiltration, or combining storm water flow with sanitary sewage.

Table 8. FLOW VARIATIONS IN SEWERS AS RELATED TO WEATHER CONDITIONS

City	Date	Daily Avg	Maximum	Minimum	Weather
Springfield	11/24/44	1.0	1.2	0.8	Dry
Springfield	11/25/44	1.9	3.5	1.1	Rain
Springfield	12/12/44	1.4	1.5	1.3	Dry
Springfield	1/6/45	4.1	4.5	3.8	Rain
Salem, Center St.	12/31/44	1.6	1.8	1.3	Dry
Salem, Center St.	1/6/45	4.3	9.5	1.8	Rain
Salem, Center St.	1/15/45	4.3	7.8	1.8	Rain
Salem, Center St.	1/21/45	0.8	1.3	0.5	Dry
Hood River	11/14/44	0.9	1.4	0.6	Cold
Pendleton	10/11/44	2.2	2.7	1.6	Sprinkle

It was impossible in some cases to secure float velocity measurements because of obstructions in sewers. As an illustration, in one instance 5 floating apples failed to travel 200 feet in 25 minutes. In one city only 50 per cent of the sewers could be measured by the float-velocity method. In another city during the driest part of the summer the 24 in. sewer was flowing more than half full because of infiltration. In still another instance the hydraulic characteristics of the sewer were such that consistent float velocity measurements

Table 9. QUALITATIVE SEWAGE AND INDUSTRIAL WASTE ANALYSIS.

City or industry and sewer No.	BOD (5-day) ppm			pH			Settleable solids in ml per l			Alkalinity ppm			Acidity ppm			Chlorides ppm		
	Max	Avg	Min	Max	Median	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
Springfield—1	130	59	20	7.7	7.3	7.0	5	2.0	0.1	105	90	68	55	23	8	28	19	14
Eugene—1	380+	240	100	7.5	6.5	4.8	40	9.5	1.1	154	93	28	60	36	6	56	36	21
Harrisburg—1	70	35	10	7.7	7.3	6.8	4	2.0	0.4	123	81	53	32	16	5	28	21	14
Corvallis—1	170	95	40	7.9	7.3	6.9	7	2.8	0.4	174	111	46	43	25	9	24	19	15
2	270	140	110	8.0	7.2	6.7	6	1.7	0.1	150	111	47	39	26	14	76	33	9
3	240	160	40	9.3	7.4	6.8	8	2.9	0.2	198	140	68	50	33	16	33	26	18
4	270	210	160	7.8	7.0	6.1	17	7.0	1.3	177	120	40	65	38	15	36	22	18
Albany—1	150	69	10	7.6	7.2	6.8	8	3.0	0.5	179	113	77	53	28	10	85	42	16
2	310	110	10	7.6	7.2	6.8	10	3.9	T	162	114	55	68	39	14	162	68	35
3	220	129	50	7.3	6.9	6.6	5	2.1	T	135	93	51	69	34	11	136	55	9
4	160	86	20	7.6	7.2	6.8	8	3.7	1.4	139	113	74	61	37	13	66	29	20
Lebanon—1	250	53	10	7.4	6.9	6.5	7	1.7	0.5	110	63	21	40	21	9	29	12	4
Independence—1	210	130	60	7.9	7.5	7.3	16	4.1	0.4	207	170	103	66	33	6	50	34	17
West Salem—1	430	279	31	7.3	6.5	3.9	26	7.5	0.3	250	79	0	213	67	13	127	43	10
Salem—1	510	244	10	7.5	6.5	4.8	31	12.0	2.0	237	134	60	297	59	11	41	23	16
2	700	282	80	7.6	6.0	3.9	50	17.0	2.0	156	93	28	377	66	6	128	42	5
3	400	240	120	7.6	6.9	6.1	28	10.5	3.0	224	154	86	107	51	12	99	64	27
Mt. Angel—1	780	432	160	7.0	5.5	5.1	7	3.0	0.6	221	211	193	82	54	38	66	52	43
Sheridan—1	190	55	20	7.8	7.3	7.0	3	1.2	0.3	118	84	46	70	20	6	36	24	14
2	80	35	20	7.8	7.4	7.1	5	1.7	0.4	102	83	59	37	15	8	36	22	14
Newberg—1	390	160	50	8.2	7.7	7.3	133	13.0	1.5	371	215	165	204	62	18	80	44	24
2	230	73	10	7.9	7.5	7.1	16	5.4	0.5	238	164	123	67	41	19	48	29	21
3	240	102	10	7.9	7.5	7.1	70	14.0	2.5	300	213	70	124	69	21	61	43	27
4	990	210	40	8.4	7.9	6.9	35	8.4	0.7	425	245	55	165	60	6	184	69	14
West Linn—1	150	78	30	7.6	7.1	7.0	10	5.6	3.0	98	75	54	53	30	16	20	18	16
2	270	120	60	7.6	7.5	7.2	50	20.7	8.0	166	140	117	70	58	53	33	31	29
3	1,230	300	40	8.8	7.3	6.7	200	33.8	5.0	470	161	68	187	52	4	165	32	8
4	870	355	40	8.1	7.3	6.0	80	33.6	3.5	511	161	43	279	77	5	280	33	5
5	1,200	370	20	8.5	7.4	3.8	490	53.5	3.0	512	187	126	312	90	8	151	32	17
6	1,260	465	60	8.5	7.4	3.8	280	68.0	3.0	974	250	78	741	106	4	216	59	10
Oregon City—1	190	69	10	7.7	7.2	6.7	50	7.9	0.7	91	65	26	58	22	8	40	18	9
2	100	36	10	7.7	7.3	6.9	12	5.2	1.1	67	51	23	26	15	3	17	13	9
3	240	63	10	7.6	7.0	6.6	9	2.5	0.5	110	54	31	37	14	4	55	14	7
4	230	84	30	7.7	6.8	4.6	13	3.6	0.7	67	48	11	28	16	7	214	41	10
5	160	60	10	7.5	7.1	6.5	11	2.5	0.4	68	41	4	27	13	4	19	11	5
6	160	58	10	7.9	7.3	6.7	7	3.3	1.2	89	63	36	40	20	4	61	21	8
7	190	75	20	11.5	7.4	6.9	10	3.3	1.4	311	77	51	148	25	10	155	21	6
8	200	65	10	7.7	7.3	6.8	8	4.0	0.7	90	70	36	37	22	11	29	15	9
9	110	60	30	7.5	7.4	6.5	14	5.5	1.7	107	79	65	43	23	10	24	18	13
10	270	125	60	7.8	7.3	6.2	17	5.5	1.0	133	86	67	49	28	9	23	18	12
11	160	66	30	7.8	7.3	6.9	6	3.1	1.0	82	63	32	37	21	5	27	15	10

Table 9. QUALITATIVE SEWAGE AND INDUSTRIAL WASTE ANALYSIS—*Continued.*

City or industry and sewer No.	Total solids ppm			Volatile solids ppm			Suspended solids ppm			Dissolved solids ppm			Grease ppm	Total bacteria 100,000 per ml		Coli aerogenes I.N. 1,000 per ml	
	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min		Max	Min	Max	Min
Springfield—1	267	200	145	144	97	37	156	67	8	205	138	32	227	19	6	10	10
Eugene—1	619	446	261	434	260	117	338	190	60	378	256	21	355	23	14	55	10
Harrisburg—1	1,205	300	169	990	190	57	198	93	38	1,007	200	77	......	......	......	......	......
Corvallis—1	435	282	184	234	131	43	260	139	64	200	153	62	265	115	2	10	10
2	463	301	112	204	130	40	194	101	40	295	200	18	484	113	4	55	10
3	600	385	248	335	192	71	260	167	110	340	218	128	71	10	1	10	10
4	1,133	475	325	948	292	152	268	177	110	980	298	164	235	640	7	1,000	55
Albany—1	483	320	213	228	149	90	198	95	24	339	225	63	......	2	1	10	1
2	554	395	287	354	223	114	348	145	56	382	250	137	......	270	4	10	1
3	560	385	237	332	201	84	324	136	78	480	249	47	......	70	11	10	1
4	482	305	193	360	180	25	268	116	30	344	189	56	......	3	2	55	1
Lebanon—1	391	180	123	297	83	19	208	56	12	310	124	9	21	1	1	1	1
Independence—1	618	400	275	376	218	100	318	133	32	335	267	77	......	......	......	......	......
West Salem—1	1,638	631	127	967	430	94	900	260	24	811	371	158	237	......	......	......	......
Salem—1	1,011	539	217	809	335	77	406	153	20	909	386	142	......	......	1	......	10
2	2,579	780	326	2,322	594	118	2,352	394	102	741	386	114	......	......	20	......	100
3	983	650	357	697	427	266	528	310	142	635	340	13	......	......	86	......	10
Mt. Angel—1	1,386	977	537	1,101	727	336	568	400	182	818	577	355	......	......	......	......	......
Sheridan—1	330	225	173	196	110	69	178	64	10	252	161	67	......	......	......	......	......
2	308	216	159	128	104	49	98	43	8	296	173	124	......	......	......	......	......
Newberg—1	6,416	995	150	4,325	555	90	2,006	355	48	6,270	640	60	......	15	1	1,000	55
2	1,211	443	300	587	226	122	820	183	52	342	260	136	......	12	10	100	55
3	2,274	780	398	1,463	400	182	1,916	485	102	465	295	134	......	18	16	55	10
4	1,829	885	398	1,260	389	81	1,664	520	10	594	365	79	......	74	18	550	100
West Linn—1	248	233	218	124	118	111	130	121	112	118	112	106	......	......	......	......	......
2	370	368	365	201	181	161	190	177	164	201	191	180	......	......	......	......	......
3	2,847	896	186	2,180	600	77	2,200	636	75	685	260	20	79	12	1	10	6
4	3,800	1,292	231	2,156	890	126	2,968	930	88	1,231	362	102	79	25	1	10	6
5	4,014	1,280	198	3,180	940	44	3,362	952	62	880	328	0	93	3	1	100	10
6	3,913	1,590	167	2,757	1,050	83	3,826	1,190	62	1,181	400	48	......	39	16	1,000	5
Oregon City—1	834	286	141	570	142	48	720	154	16	215	132	18	......	......	8	10	1
2	356	168	115	310	100	47	100	38	4	302	130	82	......	13	8	55	10
3	502	210	120	369	108	13	298	43	8	206	167	48	......	15	1	10	1
4	472	217	103	182	119	29	216	60	6	440	157	85	......	......	5	......	10
5	1,192	250	84	450	100	25	272	84	10	1,126	166	8	......	3	1	10	10
6	435	221	111	181	104	29	256	83	32	226	138	79	......	240	6	10	10
7	890	316	151	765	154	62	400	126	14	756	188	26	......	39	5	55	10
8	297	204	103	190	106	29	164	81	12	191	123	75	......	19	1	10	10
9	649	279	157	393	147	73	466	142	22	302	137	0	......	6	3	55	10
10	367	270	136	264	152	61	284	122	22	232	148	46	......	8	4	100	10
11	261	182	115	150	93	37	148	58	14	236	124	29	......	8	3	10	10

Table 9. Qualitative Sewage and Industrial Waste Analysis—*Continued*

City or industry and sewer No.	BOD (5-day) ppm			pH			Settleable solids in ml per l			Alkalinity ppm			Acidity ppm			Chlorides ppm		
	Max	Avg	Min	Max	Median	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
McMinnville—1	380	192	80	8.5	7.9	7.4	106	17.3	1.7	396	208	102	172	58	10	63	41	15
2	350	167	70	9.2	7.5	6.2	11	3.5	1.3	720	133	57	58	24	7	185	24	9
3	250	122	40	8.6	7.5	7.1	17	4.9	1.0	259	131	63	56	30	8	35	28	16
Gladstone—1	360	180	30	7.9	7.4	6.9	23	7.9	3.5	204	148	63	101	49	15	52	37	16
2	400	190	70	7.9	7.4	6.6	30	9.4	2.5	219	180	91	219	66	11	56	42	20
St. Helens—1	1,230	185	40	8.9	7.4	7.1	15	6.8	3.0	422	161	62	193	50	3	211	88	24
Oswego—1	60	...	40	7.3	...	7.2	1	...	1.0	82	...	74	38	...	32	17	...	16
2	150	...	10	7.5	...	7.4	3	...	1.5	60	...	58	12	...	2	14	...	12
3	140	...	120	7.1	...	7.0	2	...	0.7	62	...	55	23	...	18	14	...	13
Hood River—1	135	55	30	7.4	7.2	7.0	8	3.0	1.5	84	63	16	23	11	4	184	49	12
The Dalles—1	170	90	30	7.5	7.4	7.2	6	2.8	1.8	173	156	148	37	15	5	26	22	19
Pendleton—1	190	155	120	7.3	7.2	6.7	5	2.9	1.4	146	108	88	55	23	8	25	19	16
2	170	124	90	7.3	7.2	7.0	3	1.2	0.3	148	116	80	64	29	15	24	20	17
Oregon State Hospital—1	...	50	...	...	7.0	...	...	0.5	...	...	93	...	...	35	...	...	19	...
Distillery	1,970	1,450	840	4.0	3.9	3.7	468	370	220	188	142	112	794	600	400	60	42	30
Canning, Apples	450	260	130	7.2	5.8	4.7	33	13.0	3.6	56	28	8	27	11	2	83	63	53
Canning, Beets	2,200	...	1,800	4.0	...	3.8	100	...	78	...	...	...	...	...	...	...	...	...
Canning, Tomatoes	1,600	...	600	4.7	...	4.4	515	...	175	...	...	...	...	...	...	...	...	...
Brewery Slops	...	70	...	...	9.8	...	...	...	...	...	...	...	...	...	...	...	...	...
Brewery Brewhouse	...	80	...	...	2.2	...	...	...	...	...	...	...	...	...	...	...	...	...
Brewery Cellars	...	160	...	...	3.7	...	...	...	...	...	...	...	...	...	...	...	...	...
Pears Screened	...	300	...	...	4.0	...	...	...	...	...	43	...	...	146	...	...	19	...
Pears Unscreened	3,400	...	1,800	4.6	...	4.2	300	...	170	0	...	0	740	...	142	126	...	126
Linen, Caustic	...	160	...	...	11.1	...	...	...	...	...	2,690	...	...	0	...	...	...	...
Linen, Caustic Wash	...	30	...	...	9.2	...	...	...	...	...	137	...	...	18	...	...	4	...
Linen, Acid	...	10	...	...	1.5	...	...	...	...	...	0	...	...	3,800	...	...	98	...
Linen, Acid Wash	...	10	...	...	6.5	...	...	...	...	...	30	...	...	5	...	...	20	...
Woolen	...	120	...	...	9.1	...	...	33	...	...	236	...	...	4	...	...	20	...
Woolen, Rinse	...	70	...	...	7.1	...	...	0.6	...	...	61	...	...	11	...	...	4	...
Woolen, Bowl	...	600	...	...	9.4	...	does	not	settle	...	870	...	...	0	...	...	358	...
Still Bottom—1	...	12,000	...	...	5.4	...	...	...	...	...	...	...	...	...	...	...	...	...
2	...	3,800	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	...	4,200	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	...	7,200	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Table 9. Qualitative Sewage and Industrial Waste Analysis—*Continued*

City or industry and sewer No.	Total solids ppm			Volatile solids ppm			Suspended solids ppm			Dissolved solids ppm			Grease ppm	Total bacteria 100,000 per ml		Coli aerogenes I.N. 1,000 per ml	
	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min		Max	Min	Max	Min
McMinnville—1	4,901	1,280	276	2,065	535	82	4,182	931	38	1,643	349	139	......	......	3	......	100
2	680	310	232	281	161	58	190	93	14	579	217	83	......	......	6	......	10
3	858	317	202	250	158	49	410	116	38	448	203	72	......	......	5	......	6
Gladstone—1	512	362	232	273	196	112	354	157	36	294	205	41	......	29	2	550	10
2	918	485	258	566	270	123	562	223	46	463	262	90	......	......	640	......	10
St. Helens—1	1,122	495	209	601	248	106	396	150	30	984	345	115	......	690	7	55	6
Oswego—1	254	......	182	102	......	81	44	......	24	230	......	138	......	......	......	......	......
2	208	......	203	153	......	72	30	......	12	191	......	178	......	......	......	......	......
3	284	......	132	106	......	81	48	......	10	274	......	84	......	......	......	......	......
Hood River—1	1,520	420	204	680	290	79	112	63	4	1,460	357	169	......	......	......	......	......
The Dalles—1	3,620	997	400	2,100	573	158	220	117	28	3,560	880	248	......	......	......	......	......
Pendleton—1	597	450	370	392	254	40	388	211	140	261	239	192	......	......	......	......	......
2	520	362	197	318	181	76	168	106	56	420	256	105	......	......	......	......	......
Pendleton State Hospital—1	......	257	......	......	136	......	......	86	......	......	171	......	......	......	......	......	......
Distillery	13,200	10,000	3,830	12,680	10,000	3,650	2,640	2,400	2,220	10,980	7,600	1,520	......	......	......	......	......
Canning, Apples	5,570	1,330	460	4,680	1,000	219	292	110	30	5,280	1,220	310	......	......	......	......	......
Canning, Beets	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Canning, Tomatoes	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Brewery Slops	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Brewery Brewhouse	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Brewery Cellars	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Pears Screened	......	384	......	......	319	......	......	140	......	......	244	......	......	......	......	......	......
Pears Unscreened	40,000	......	33,000	35,700	......	31,700	19,000	......	18,000	22,000	......	14,000	......	......	......	......	......
Linen, Caustic	......	45,000	......	......	26,600	......	......	800	......	......	44,200	......	......	......	......	......	......
Linen, Caustic Wash	......	409	......	......	305	......	......	46	......	......	363	......	......	......	......	......	......
Linen, Acid	......	4,920	......	......	4,379	......	......	74	......	......	4,846	......	......	......	......	......	......
Linen, Acid Wash	......	98	......	......	68	......	......	8	......	......	90	......	......	......	......	......	......
Woolen	......	1,146	......	......	808	......	......	552	......	......	594	......	......	......	......	......	......
Woolen Rinse	......	238	......	......	121	......	......	92	......	......	146	......	......	......	......	......	......
Woolen Bowl	......	27,300	......	......	15,650	......	......	16,800	......	......	10,500	......	......	......	......	......	......
Still Bottom—1	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
3	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
4	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

were not obtainable. The survey was of considerable assistance in pointing out leaks in water mains, clogged sewers, buried manholes, physical location of sewers, and unauthorized connections.

4. **Industrial wastes.** The characteristics of the industrial wastes sampled in this survey are shown in Table 8. Pulp and paper mill wastes and flax retting wastes were not sampled because these were adequately covered in a previous survey. See Bulletin No. 7, Engineering Experiment Station, to which reference has already been made.

Cannery wastes were sampled for their qualitative characteristics. Quantitative data can only be determined on a unit of pack measurement. These data cannot be completed until all questionnaires supplied to typical canneries early in the survey are returned with information.

Observation of some packing plants and canneries revealed a general lack of understanding of the problems of waste disposal and stream pollution. In some instances there were evidences of considerable expenditures made for screening and partial treatment without proportionally beneficial results. The costs of screening and hauling were brought out in the course of investigation and it was learned that in Salem alone between $15,000 and $20,000 was spent for this purpose per season.

Flax retting plants scattered throughout the valley and located on small tributary streams are not making adequate provision for treatment of their wastes. The pea canning industry of eastern Oregon was shut down before the survey was fully started and so no waste was available for analysis.

VI. SEWAGE AND INDUSTRIAL WASTE TREATMENT

1. **Results to be accomplished.** The factors that regulate the condition of a stream have been enumerated and the consequences of dumping untreated domestic sewages and industrial wastes have been described. To avoid these consequences and restore the full utility and beauty of the rivers a program of comprehensive and intensive treatment of all wastes, except those diffused wastes originating in agricultural areas, should be established.

The following general discussion is concerned with the methods by which this may be accomplished. There are three major functions accomplished in sewage and waste treatment:

a. Reduction in the BOD of sewage and waste.
b. Reduction in the bacterial concentration, and elimination of the pathogenic forms.
c. Removal or alteration of the gross physical characteristics which are so apparently offensive.

The first two functions are least understood by the general public. The second function is assumed to be achieved by the accomplishment of the third, whereas in reality if the first two functions are achieved the third is automatically included.

2. **Available methods.** There are two basic ways in which the BOD of sewages and industrial wastes may be reduced. One is to separate the solid and liquid putrescible material from the sewage and waste, leaving an innocuous liquid, and the other is to supply oxygen in one of several ways so that the waste is oxidized and rendered stable. By a combination of the foregoing

methods the great bulk of the bacteria will be eliminated. Efficiencies as high as 99.2 per cent have been achieved in respect to total bacteria and 99.8 per cent of Coli aerogenes.[1] The effluents from such refined treatment are not readily distinguishable from natural waters. The biological lakes of the Ruhrverband in Germany have been developed from the sewage effluents of the thickly populated Ruhr Valley. These artificial lakes, the equals of the famous natural lakes of Bavaria, are the excellent recreational areas of Essen, an example of conservation in striking contrast to the use of rivers in other places as open sewers.

Separation of the settleable putrescible matter is usually accomplished by allowing it to settle out in large tanks where the sewage is quiescent. The heavy putrescible matter settles to the bottom and the light greases and oils rise to the surface. Both are removed by circular sweeps and segregated for further treatment which will be discussed later. In some cases chemicals are added to the incoming sewage to precipitate fine particles, known as colloids, and increase the amount of material that can be removed. The removal of the settled material removes about 35 per cent of the BOD of the original sewage. The bacterial removal is considerably higher.[2] In general, this method is known as a primary treatment; where chemicals are added it is known as a chemical treatment.

Figure 14. U. S. ENGINEER DEPARTMENT DREDGE AT WORK.

[1]Phelps, E. B., Stream Sanitation, 1944. John Wiley and Sons, Inc., New York. Page 193.
[2]Keefer, C. E., Sewage-Treatment Works, 1940. McGraw-Hill Book Company, Inc., New York. Page 125.

Treatments of the primary effluent are known as secondary treatments, and are oxidation processes wherein atmospheric oxygen is provided in one of several ways to build up and maintain a biological population that utilizes as food most of the remaining organic waste that is in colloidal and dissolved forms. This secondary process is performed in several ways:

a. Sprinkling the primary effluent over sand or rock beds where large biological surfaces have been developed from the previous doses.

b. Agitation of the primary effluent with compressed air, brushes, or paddles with addition of settled sludge from the effluent of this process to provide a "zoogloea mass" or biological surfaces that stabilize the sewage in a like manner.

Variations of the two basic methods include recirculation of effluents from the rock beds or additional agitation of the circulating sludge. The foregoing methods are known as sand filtration, trickling filter, and activated sludge treatments. The latter two processes are generally followed by secondary settling to remove the humuslike sludge.

Table 10. EFFICIENCIES OF TREATING PROCESSES.

Treatment	Removal
Sand filters	98.0%-99.0% of BOD 98.0%-99.0% Bacteria
Trickling filters	75.0%-80.0% BOD up to 90.0% Bacteria
Activated sludge	87.0%-94.0% BOD 99.2%-99.8% Bacteria

These are the basic processes of sewage and industrial waste treatment and may be known under a variety of patented process names.

In many instances, the effluent from primary treatment or from secondary treatment plants is disinfected with some sterilizing agent such as chlorine. This practice is resorted to where water supply intakes are located short distances downstream from the sewage treatment plant outlets. In other instances this procedure is used where the water is used for recreational purpose or where the receiving stream is very small. The chlorine is used up rapidly and has disappeared from the effluent before it reaches the river.

The putrescible settled solids from the primary and secondary sedimentation tanks are generally pumped into one or a series of closed tanks. Digestion by anaerobic bacterial action is controlled by providing an ideal environment for bacteria and higher forms of life. The temperature of the digesters is maintained at approximately 90 F and the heat for this purpose is provided by the gas evolved as a byproduct of the digestive process. The other end products of the process are water and a fibrous sludge which is dried either mechanically or on sand beds. This sludge is practically stable, as well as inoffensive, and can be used safely as a fertilizer for field crops, orchards, and lawns.

3. **Utilization of fuel gas generated.** In a properly operated plant there is an excess of gas over and above that needed to maintain the digesters at the right temperature. This gas has a heat value of about 600 Btu per cubic foot, which is comparable to the quality of manufactured gas. There is a definite trend toward utilization of the gas in gas engines which directly or indirectly furnish most of the power requirements of the plant itself. The

digesters in this case are heated by the cooling water from the jackets of the engines. Considerable economies have been achieved by such well planned utilization.

4. **Home garbage disposal units.** Another development of considerable magnitude may be predicted due to the introduction of home grinding units for garbage disposal. If these currently advertised appliances receive popular acceptance the following effects may be expected: increase in water consumption and corresponding increases in sewage flows; deposition in poorly laid or partly clogged sewers; increase in BOD total, suspended, volatile, dissolved, and settleable solids; increase in load in primary sedimentation which may prove beneficial; and increase in digester and sludge bed capacity. There will also be a larger output of gas and sludge which will undoubtedly make the salvage value of these two products more significant.

5. **Treatment of industrial wastes.** Industrial waste treatments depend on the types and the volumes to be treated. Some wastes can be mixed with city sewages and economically treated, while others would be of such strength or volume that they must be treated separately. It would seem logical that the cost of waste treatment is an essential part of the manufacturing cost.

The wastes from a small industry may be absorbed in the sewage treatment plant of a large city without perceptible deleterious effect, whereas the same wastes discharged into the treatment plant of a small community may be disastrous to operation. Highly acid or alkaline industrial wastes or wastes containing sugar, protein, or fat offer considerable difficulty when mixed with domestic sewage. The effect on the pH, which is a controlling factor in the biological environment in primary and secondary treatment and sludge digestion, could easily by disastrous, particularly where indiscriminate or batch dumping is practiced. Wastes with dissolved sugar content are practically unaffected by primary treatment and place an excessive burden on secondary treatment processes unless adequate provisions have been made to handle them.

Protein and fat wastes carry a high BOD and fats in particular increase the problems of operation of primary and secondary processes and lengthen the digestion period required unless extreme care is taken in operation. Special mechanisms will be needed to skim the grease from the liquid surface of the sedimentation tank, and to date the problem of grease removal and disposal has not been satisfactorily solved from an operational standpoint.

From the foregoing it can be seen that the treatment of industrial wastes is a highly specialized problem. Few cities can afford to accept the industrial wastes without pretreatment and adequate compensation.

VII. CONCLUSIONS AND RECOMMENDATIONS

1. **Rivers.** The Willamette River was found to be seriously polluted and grossly contaminated in August and September of 1944 from Salem north to Portland. Comparison with the sanitary survey of 1929 establishes the fact that this critical condition is rapidly progressing upstream. In addition it should be emphasized that the river is grossly contaminated just below Eugene.

It is recommended that the upstream degrading be stopped at the earliest possible time and the critical conditions determined by this survey be subjected to more intensive investigation to determine the proportional loads of various wastes discharged into the river. The river should be sampled and analyzed as a check on the effectiveness of sewage and industrial waste treatment.

Allowable organic loads should be determined by an intensive deoxygenation and reaeration study of reaches of the river between points of pollution. The effect of impounding water in storage lakes upon the dissolved oxygen in the lakes should be included in this project.

Extensive sludge deposits in lagoons and back waters of the river were discovered adjacent to points of domestic and industrial waste disposal. It is indicated that these septic deposits are a serious oxygen exhausting source, incubators of bacteria, and lethal to fish food organisms. It is important that their origin be traced and their effect on stream conditions established.

River banks were found to be the accepted dumping areas for all manner of rubbish, garbage, and metal scrap. This insanitary litter nurtures a thriving rodent population, depreciates the value of adjacent property, precludes any recreational use of the area, and constitutes a civic disgrace. Communities should be aroused to full cognizance of this situation.

The interest and cooperation of the personnel of the river ferry service was found to be of great value. The experience of these river men should be utilized in making records and notes of stream heights, temperatures, and general river conditions. These records would be of value to the Highway Department, the Sanitary Authority, and the ferrymen themselves.

Sampling of tributary streams, which was of necessity incidental to the survey, indicated that many creeks and small rivers flowing into the Willamette were grossly contaminated and imposed a heavy pollutional load upon the main river. A more extended study of tributary streams should be carried out.

It was observed that small rivers and creeks adjacent to populated areas are the accepted disposal medium for human and industrial wastes without regard for their capacity to absorb the burden. For example, the Umatilla river within a single mile of its course receives the effluent of the inadequate Pendleton disposal plant, untreated commercial and domestic wastes from the urban fringe, and the septic tank drainage from the State Hospital. A state of gross contamination and heavy pollution results, and persists for a length of 5 miles down stream. From a large flour mill near Athena the drainage of Wild Horse Creek was literally choked by excessive wastes.

Seasonably dry water courses commonly employed as disposal areas in rural districts discharge an accumulated burden into receiving streams when swept by flash floods or rejuvenated by seasonal rains. In this way they act to intensify the severity of the pollutional burden carried to main river flows with the first fall runoff. Attention is called to the disposal of sewage in areas adjacent to city limits. Samples taken from ditches less than 20 feet from houses were found to have BOD's equal to the sewage of the adjacent town. Children from these homes were playing in this material.

2. **City sewages.** This report can be considered a progress report of the quality and quantity of most of the important city sewages in the Willamette Valley and for three cities in eastern Oregon. A start has been made and instructions have been given for the continuance of the quantitative measurements. The quantitative data for those cities that have installed weirs and recorders will be inestimably valuable in both sewer replacement programs and sewage treatment design. The qualitative analyses of those sewages where extended samplings were made give an adequate picture of the particular sewage. These analyses also are of great value for future plant operation and in locating sources of other than domestic wastes.

Volumetric studies of sewages of those cities that participated in the survey should be made as complete as the qualitative analyses. Cities should be directed to install weirs and recording instruments for this purpose.

Cities that have no basic qualitative and quantitative data should participate in a similar survey or furnish the necessary data to the State Sanitary Authority.

Physical inspection of sewers, as well as float measurements, revealed that several sewerage systems are breaking down through old age, root encroachments, superimposed loads, chemical action, or settlement. It was noticeable in some so-called sanitary sewers that infiltration from ground water must have reached the sewer through open joints. In some instances, contrary to city ordinances, roof drainages from buildings and homes was placing an unwarranted burden on the sewerage systems which were not designed for this purpose. Wash-down water mixed with gasoline, grease, and oil was found in many sewers. Because of the physical condition of some of these sewerage systems that have served their purpose and are now approaching obsolescence it would seem logical for these cities to initiate a program of replacing obsolete combined sewers with smaller sanitary sewers. The old sewers will still serve adequately as storm overflows with minor changes. Such a program will diminish the capital investment required for treatment plants. It will also improve the efficiency of plant operation since treatment plants cannot be economically designed to handle large storm flows.

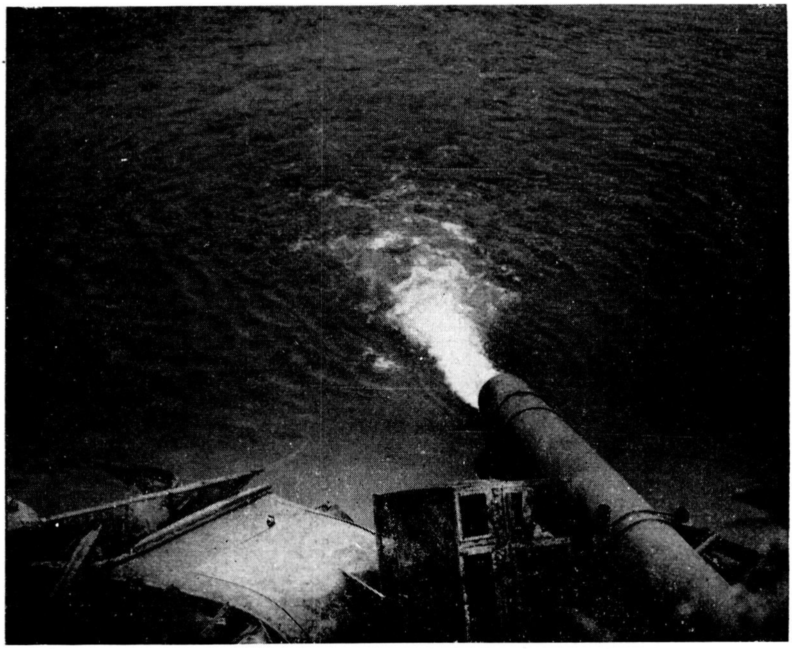

Figure 15. Typical Sewer Outlet and Rubbish Heap.

An economic study of the sewer system in connection with sewage treatment may indicate that a divorcement of the sanitary sewage from the storm drainage will be advisable in many communities.

Inspection of sewage treatment plants throughout the state brings the conviction that there is an urgent need for a training program for treatment plant operators. The variable and perishable characteristics of sewage demand competent direction and trained personnel in treatment plants. Without such operation the most adequately designed plant becomes a nuisance and liability.

If sewage treatment and stream purification are to hold their present impetus, there must be no repercussion from a disillusioned public that spends tax dollars for sanitary disposal and finds that it has succeeded only in concentrating a nuisance.

The critical condition of the river during periods of low flow and high seasonal burdening, indicates that secondary treatment will be necessary for at least a portion of the year for many communities. It is suggested that all communities be advised to investigate the pollutional burden that they will be allowed to release before deciding on appropriations for treatment plants.

Observation of domestic sewages reveals that many sewers carry considerable amounts of garbage. It can be foreseen that this method of disposal will be extended after the war when appliance manufacturers put household garbage grinders on the market. Account must be taken of this expected load in predicting the size and character of treatment plants required and in anticipating the effect of sewage effluents on the stream condition.

Garbage disposal through sewers will also result in increased gas production and sludge residue from treatment plants. Increased volume of these two digestion products will make their utilization more practicable. The production of larger volumes of methane gas will in particular indicate an increased use of sludge-gas engines for treatment plant power and sewage pumping as well as for heating.

3. **Industrial wastes.** The following types of industrial plants impose large burdens on the Willamette River and its tributaries: pulp and paper mills, flax retting plants, packing houses, abbattoirs, canneries, dehydrators, creameries, and textile mills.

In eastern Oregon the pea canning industry imposes the most difficult problem common to that area. Distillery and other cannery wastes are increasing.

4. **Pulp and paper mill wastes.** The sulfite liquor problem is one of the oldest and most difficult of sanitary disposal. Extensive and prolonged series of researches have been carried on for many years and at the present time intensive studies on the utilization and alleviation of this material are being carried out in the Northwest at the University of Washington, Weyerhaeuser Timber Company at Longview, and the Crown Zellerbach Corporation at Camas, Washington. All of these studies are being financed by the pulp and paper industry.

As a result of this research an economic solution has been developed and the following quotation from a letter to the authors from Dr. R. S. Hatch, Director of Research for the Pulp Division of the Weyerhaeuser Timber Company, explains the method to be employed at Longview, Washington:

"RECOVERY PROCESS FOR SULFITE WASTE LIQUOR
INVOLVING THE USE OF MAGNESIA BASE COOKING ACID

"Over a period of the past ten years the technical staff of the Howard Smith Paper Company of Cornwall, Ontario, working in conjunction with the Babcock and Wilcox Company of New York City, and the Weyerhaeuser Timber Company have been engaged in the development of a cyclic cooking and recovery process for the manufacture of sulfite pulp. This involves the evaporation and burning of the sulfite waste liquor in a recovery plant designed to utilize the heat evolved in the burning process for the generation of steam and power with the simultaneous recovery of the magnesia base and sulfur used in the preparation of the original cooking acid.

"In the past, many attempts have been made to evaporate and burn sulfite waste liquor resulting from the conventional sulfite process in which lime is used as a base. Attempts to do this have been beset with many difficulties. From the evaporation standpoint, insoluble lime salts are formed in the evaporation resulting in the scaling of evaporator tubes and serious loss in heat transfer efficiency as well as an increase in the cost of evaporation through excessive maintenance charges resulting from the cleaning and replacement of evaporator tubes. Furthermore, in the burning process the lime present in the evaporated waste liquor combines with the sulfur present to form calcium sulfate ash, which is of little value.

"When magnesia is used as a base for preparation of the cooking acid, no difficulties are experienced in the scaling of evaporator tubes because the magnesia salts existing in the waste liquor are readily soluble. When the concentrated waste liquor is burned in suspension under suitable combustion conditions, the sulfur present passes off in the combustion gases as sulfur dioxide, while the magnesia is recovered from the outgoing combustion gases as a finely divided caustic magnesium oxide. This magnesium oxide ash is collected by suitable equipment and made into a slurry with water. This slurry is then used in suitably constructed, packed towers to absorb the sulfur dioxide from the combustion gases, thus regenerating cooking acid.

"With suitably designed equipment for the evaporation, burning, and chemical recovery, a very high percentage of the chemicals used in the cooking process may be recovered. Calculations based on pilot plant operations both at the pulp mill of the Weyerhaeuser Timber Company in Longview and the pulp mill of the Howard Smith Paper Company in Cornwall, Ontario, have indicated that a proper choice of evaporating equipment, boiler design, and boiler pressure will enable a mill so designed to generate substantially all of the steam and power required for the process and at the same time reduce the purchase of chemicals used in the cooking process to an amount approximating between 5 and 10 per cent of the quantity customarily consumed when employing the present lime base cooking process.

"Because every effort is made in this process to recover all of the waste liquor resulting from the cooking of the wood, there will be none discharged into the streams.

"As a result of the data obtained from the operation of the two pilot plants mentioned above, complete plans have been prepared for the installation of the recovery process at the pulp mill of the Weyerhaeuser Timber Company in Longview, Washington, but construction has been delayed because of the lack of critical materials as a result of the war. As soon as these materials are available it is expected that the company will go ahead with construction and will be in a position to demonstrate the feasibility and economy of the process."

Other solutions in the economic utilization of this complex material may appear from the above mentioned intensive research program.

5. **Flax plant wastes.** Stream pollution from flax plant wastes has increased in volume several times since 1933. It has a high oxygen demand. Some form of treatment, either utilization or alleviation, must be found to reduce this load. Biological treatment to reduce the oxygen demand may conceivably be used. Treatment, as suggested in Bulletin No. 7 of this Station, is too expensive.

6. **Cannery and miscellaneous wastes.** The soft fruit and vegetable wastes present a similar problem to that of flax. The sugar in these wastes is the cause of the large oxygen demand. Treatment of them by oxidation is imperative if the rivers are to be brought back to a reasonable degree of purity. Successful methods have been developed for such treatment of the sugar waste. Use should be found through research for the peelings, cores, and culls now extravagantly wasted. This wastage is a distinct loss to the farmers and canners of the state, and research methods financed by the industry should be applied. Agricultural use of this material is suggested in preference to the present method of grinding and discharging into the river or dumping untreated on to land.

The data in Table 11, in thousands of cases of product, taken from the Western Canners and Packers Magazine, April 1944, indicate the development in this widespread industry in the states of Oregon and Washington.

Table 11. FRUIT PACK DATA FOR OREGON.
(In thousands of cases).

Year	Total	Fruit packed				
		Pears	Prunes	Apples	Apricots	Peaches
1942	4,112	1,772	795	249	72	227
1943	4,582	1,047	1,586	237	0	219

The total vegetable pack of Oregon and Washington in the years 1921-1930 averaged 678,000 cases, 728,000 in 1932, 5,392,000 in 1936, 10,558,000 in 1942, and 13,200,000 in 1943. The pea crop for the two states averaged 105,000 cases in 1921-1930, 850,000 in 1934, and 7,000,000 cases in 1943. The location of the pea canning industry has changed materially over the years. Oregon and Washington's output is exceeded only by Wisconsin. When it is realized that approximately 40 per cent of a pear is wasted in the canning process, the magnitude of the waste problem can be realized. Dr. E. H. Wiegand, head of Food Industries Department at Oregon State College, estimates that out of 4,700,000 cases of fruits and vegetables packed in Salem there is a waste of 9½ million pounds of fruit and 21 million pounds of waste vegetables.

Slaughter houses are serious offenders in the disposal of their wastes and are usually located outside city limits. Refuse from this industry is dumped in numerous ways into small creeks or drainages.

The larger packing plants usually make some effort to recover byproducts but dispose of their liquid wastes without treatment into city sewers.

Textile mill wastes are dumped untreated into tributary streams or city sewers with little or no treatment.

7. **Concluding remarks.** Treatment processes are well established for many of the foregoing wastes, but indiscriminate acceptance by cities of all industrial wastes without consideration of quality or quantity may lead to serious operational complications when sewage treatment is introduced.

It is pointed out that a thorough inventory of industrial plants, processes, operating seasons, products, and wastes is needed. This information should include quality and quantity of wastes in terms of manufactured product. To facilitate this, plant plans should be available showing locations and dimensions of sewers and outlets. Weirs and recorders should be installed, as in the cases of cities, to measure these wastes and to establish units of waste measurement.

APPENDIX A
RECORD SHEET FOR RIVER SAMPLES

Engineering Experiment Station
Oregon State College
Project 50

RIVER STUDIES FIELD SHEET

Sheet Number

Date	Station	Time	Temp	DO Bottle Number	BOD Bottle Number	Bact Bottle Number	Remarks

Collected by..

APPENDIX B

INSTRUCTIONS TO CITY ENGINEERS

A. QUANTITATIVE MEASURING.

1. INSTALLATION OF RECORDER.
   a. Mount on knee brackets well above highest flows in winter.
   b. Options:
      1. In manhole.
      2. In offset made by knocking out section in side of sewer.
      3. In temporary bypass line.
   c. Locate recorder above measuring device to measure head of sewage.
   d. Stilling well.
      6″ pipe for float, $\frac{3}{8}$″ drilled in down stream side—pipe to extend full height of float range.

2. INSPECTION AND SERVICE OF RECORDER AND RECORDS.
   a. Follow instructions of manufacturer.
   b. Float and cable must be checked to see that float is free.
   c. Wind clock at prescribed intervals.
   d. Mark depth in inches of sewage, time and date on chart, at beginning and end of run—daily or weekly.
   e. See that holes in stilling well are clean and no deposits are allowed to accumulate.
   f. Remove record chart and deposit with city engineer who will turn it over to field engineer or assistant. Two prints will be made of this in Corvallis and city will be charged with cost of prints. One print and the original will be returned to the city.

3. MEASURING DEVICES.
   a. Types:
      1. Flume—Parker Bowlus, Parshall.
      2. Hump control.
      3. Sloping weir.
   b. Factors to be considered.
      1. Accuracy.
      2. Simplicity of manufacture.
      3. Cost.
      4. Sludge deposition.
   c. Data obtained from recorders will be changed from float depths into discharge in cubic ft/sec, gallons/min, or gallons/day by Experiment Station force. Results will be given to city when these are completed.

B. SAMPLING BY CITY FORCES.

1. THE IMPORTANCE OF SAMPLING.
   a. The value of sampling depends upon the adequacy of the sampling.
   b. The precision used in the laboratory will be wasted if sampling is not honestly and accurately done.
   c. Quality and quantity changes throughout the day.

2. COMPOSITE SAMPLING.
   a. A composite sample consists of a series of samples taken from the same point at equal intervals of time. The samples which are measured in proportion to the flow at the time of sampling are added together in the same container. Each trunk sewer will require a separate container.
   b. Composite samples in this survey will be made over a 24-hour period at hourly intervals.
   c. If city has only one trunk sewer discharging into receiving stream or river, then one 24-hour composite sample shall be taken on each scheduled day. If city has two trunk sewers then two 24-hour composite samples shall be taken on each scheduled day, etc.
   d. It is hoped that sampling will be done so as to represent three weeks of sewage flow during dry weather period. This dry weather sampling will extend over an eight or ten week period depending upon schedule. For example, a city may sample on Monday and Thursday of first week, Tuesday and Friday of second week. This schedule can be worked out immediately following this meeting.
3. SAMPLING POINTS.
   a. Should be in manhole near outlet of each trunk sewer discharging into river.
   b. Should be easy to reach by truck.
   c. On even grade—no or minimum deposits in sewer.
   d. Near recorder and measuring device.
   e. Should not be flooded out.
4. PHYSICAL SAFEGUARDS FOR SAMPLING CREW.
   a. Barriers to protect sampling crew.
   b. Two on a team if possible.
   c. Police advised of survey.
   d. No open flame in sewers.
5. MATERIALS AND SUPPLIES FOR SAMPLING TO BE PROVIDED BY CITY.
   a. Two (2) large cans with bails, 4 or 5 gallon each. Mark "A" and "B" for each trunk sewer. Have one extra emergency can.
   b. Simple wood box, insulated with sawdust to hold "B" cans. Room in box for ice to be packed around cans. Good insulated lid on box. This box can be kept in pickup.
   c. Several sampling dippers, wide mouth, 5 in. or 6 in. diameter—6 in. to 1 ft deep, weighted or balanced and attached to stick or rope. (Alternative—pitcher pump with large suction and no screen).
   d. Two measuring jars (quart Mason jars), graduated (painted or shellacked adhesive tape on outside) for each sewer. (See graduation scale. This scale is for circular sewers only. If other shapes advise field engineer immediately).
   e. Any simple wood paddle.
   f. Measuring stick graduated in inches.
   g. Clipboard for the data sheets which are provided by Engineering Experiment Station.
   h. Flashlights.

6. Method of Sampling (City Forces).
   a. Stir sewage with paddle to prevent picking up sludge deposits. Wait two minutes to get even flow.
   b. Measure depth of sewage.
   c. Record on data sheet:
      1. Name or location of sampling point.
      2. Date—day and hour.
      3. Depth of flow.
      4. Weather, fair, rain, etc.
      5. Temperature—air and sewage.
      6. Notes on character of sewage — greasy, strong odor, gasoline odor, trash, grass, pear peelings, beets, muddy, etc. (This information will be helpful to chemists now and city later).
   d. Scoop up nine or ten dippers of sewage and pour into can A. Dipper should go well down into flow but not scrape bottom.
   e. Stir contents of can A thoroughly and fill measuring jar to depth of sewage flow.
   f. Pour contents of jar into can B—don't spill. If can B is filled use emergency can and mark.
   g. These steps should be followed to the letter and in this order. They should be repeated at each sampling point once each hour for 24 hours.
   h. A crew can make a circuit of sampling points but the samples at any given point should be taken one hour apart.
7. Care of Sample and Equipment.
   a. Can B must be kept in box, packed in ice and in shade to decrease bacterial growth.
   b. Samples in cans B will be picked up by Station's Field Assistant at agreed points from sampling crew. Field assistant will have truck and special cans. He will pour the samples into these cans and immediately return city equipment to city crew. Ice from city wood box should be saved for Field Assistant's box.
   c. Sample cans A and B and dippers should be washed with hot soapy water, rinsed, and all equipment left in order for next run.
   d. Responsibility for delivering sample to field assistants in good condition is city's responsibility to avoid loss of sample in case of transportation delay.
   e. Schedule of sampling must be adhered to. Field assistant will have a rigid schedule on each trip and failure of one city will upset other cooperating cities and laboratory at Corvallis. The laboratory must examine the sample that same day. If there is an unavoidable delay in city's sampling, it is suggested that the 24-hour sample be sent to Corvallis by city pickup and send field assistant on his regular schedule.
   f. It is suggested that sampling crew practice before actually making a schedule run in order to develop technique and eliminate "bugs." Field Engineers will be available to help, but cannot be in each city immediately.

APPENDIX C

FIELD RECORD SHEET FOR CITY SEWAGE SAMPLES

State Sanitary Authority

Stream Pollution Studies in Oregon—1944
Engineering Experiment Station, Corvallis
Tel. 620—Ext. 121

CITY SEWAGE SAMPLING DATA SHEET

City .... Sewer ....

Date .... Location ....

Sampling crew .... Size.............................. Shape..............................

Time of sampling		Depth of sewage	Temperature		Remarks on weather	Remarks on condition of sewage
Hour	Min.		Air	Sewage		

Exp't Station Project 50

Picked up by ....

Date and time ....

Remarks

....

....

APPENDIX D

FORM FOR CITY SEWAGE SAMPLING SCHEDULE

Engineering Experiment Station

1944

SCHEDULE FOR CITY SAMPLING

DRY WEATHER SAMPLING PERIOD

Date	Week	Days of week and zones						
		M	T	W	Th	F	Sat	Sun
July 31-Aug. 6	1	1	2	3	1	2	3	....
Aug. 7-Aug. 13 ..	2	....	1	2	3	1	2	3
Aug. 14-Aug. 20 ..	3	3	....	1	2	3	1	2
Aug. 21-Aug. 27 ..	4	2	3	....	1	2	3	1
Aug. 28-Sept. 3 ..	5	1	2	3	....	1	2	3
Sept. 4-Sept. 10 ..	6	3	1	2	3	....	1	2
Sept. 11-Sept. 17 ..	7	2	3	1	2	3	....	1
Sept. 18-Sept. 24 ..	8	1	2	3	1	2	3	....
Sept. 25-Oct. 1 ..	9	3	1	2	3	1	2	3
Oct. 2-Oct. 8	10	....	3	1	2	3	1	2
Oct. 9-Oct. 15	11	2	....	....	....	....	....	1

Sampling at longer intervals for wet weather flow through Dec. 1944.

ZONE 1 Cottage Grove, Creswell, Oakridge, Springfield, Coburg, Harrisburg, Junction City, Eugene, Corvallis.

ZONE 2 Monmouth, Independence, Dallas, Albany, Jefferson, Lebanon, Falls City, Sweet Home, Sheridan, Willamina, Salem, West Salem, Stayton, Scio.

ZONE 3 Oregon City, West Linn, Oswego, Milwaukie, Canby, Aurora, Dayton, Hubbard, Woodburn, Molalla, Amity, Lafayette, Beaverton, Sherwood, Cornelius, Gladstone, Sandy, Mt. Angel, Forest Grove, McMinnville.

OREGON STATE COLLEGE
ENGINEERING EXPERIMENT STATION
CORVALLIS, OREGON

LIST OF PUBLICATIONS

Bulletins—

No. 1. Preliminary Report on the Control of Stream Pollution in Oregon, by C. V. Langton and H. S. Rogers. 1929.
Fifteen cents.

No. 2. A Sanitary Survey of the Willamette Valley, by H. S. Rogers, C. A. Mockmore, and C. D. Adams. 1930.
Forty cents.

No. 3. The Properties of Cement-Sawdust Mortars, Plain, and with Various Admixtures, by S. H. Graf and R. H. Johnson. 1930.
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No. 4. Interpretation of Exhaust Gas Analyses, by S. H. Graf, G. W. Gleeson, and W. H. Paul. 1934.
Twenty-five cents.

No. 5. Boiler-Water Troubles and Treatments with Special Reference to Problems in Western Oregon, by R. E. Summers. 1935.
None available.

No. 6. A Sanitary Survey of the Willamette River from Sellwood Bridge to the Columbia, by G. W. Gleeson. 1936.
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